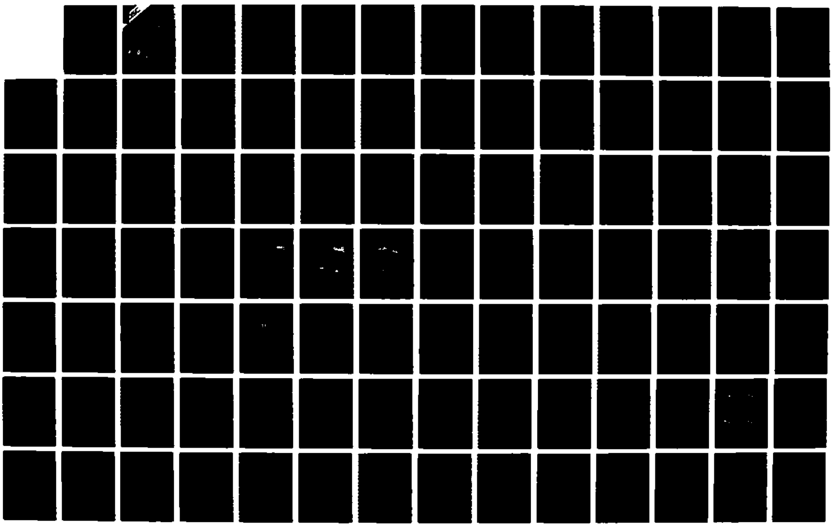
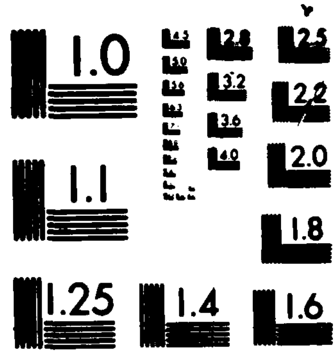
AD-A183 934 DISTRIBUTION ABUNDANCE BEHAVIOR AND BIOACOUSTICS OF 1/5
ENDANGERED WHALES IN T..(U) NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO CA D K LJUNGBLAD ET AL. JUL 87 NOSC/TR-1177
UNCLASSIFIED F/G 8/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

NOSC

NAVAL OCEAN SYSTEMS CENTER San Diego, California 92152-5000

NOSC TR 1177

Technical Report 1177
July 1987

Distribution, Abundance, Behavior, and Bioacoustics of Endangered Whales in the Alaskan Beaufort and Eastern Chukchi Seas, 1979-86

Donald K. Ljungblad
NOSC

Sue E. Moore, Janet T. Clarke, and John C. Bennett
SEACO, Inc.

Prepared for
Minerals Management Service
Alaska Outer Continental Shelf Region
U.S. Department of the Interior

NAVAL OCEAN SYSTEMS CENTER

San Diego, California 92152-5000

E. G. SCHWEIZER, CAPT, USN
Commander

R. M. HILLYER
Technical Director

ADMINISTRATIVE INFORMATION

The work discussed in this report was performed during the period August through October 1986 under the sponsorship of the Minerals Management Service, Alaska, OCS Region, U.S. Department of Interior.

Released by
L.W. Bivens, Head
Biological Sciences Branch

Under authority of
H.O. Porter, Head
Biosciences Division

ACKNOWLEDGEMENTS

We wish to acknowledge the professional assistance of those people who contributed to our safe and successful season. At the Office of Aircraft Services (OAS), U.S. Department of Interior, Anchorage, AK, we cite the safe and persevering performance of pilots Tom Belieu, Bill Belinski, Gary Candee, Dale Moore, and John Warren, and the OAS maintenance and administrative staffs in providing the Grumman Goose (N780). Evergreen Helicopters, Inc. of Anchorage, AK, provided the Twin Otter aircraft (302EH) and pilots Ken Conkey, Bud Graham, Mike Koskovich, and Frank Walter. At Minerals Management Service (MMS), we appreciate the advice and support of Cleve Cowles, Jerry Imm, Jerome Montague, and Steve Treacy. In the field, observers Ada Fowler, Eric Gross, Matt Hare, Peter Johnsen, John Morton, Tom Rickman, and Chris Vrolijk of SEACO, Inc. proved to be invaluable to our aerial survey efforts. The success of the Barter Island acoustic station was largely due to the efforts of John Hayne of SEACO, Inc. and the logistics support of Mike Feda Beckmann, Joe Bell, Landon Parker, Blackie Robinson, Randy Unfred, of the Barter Island DEW line. For logistics assistance in Deadhorse and Barrow, we thank Bob Jenkins and Joe Mathis of NANA Services and the Bensons at the Barrow Airport Inn.

Richard O'Hara of SEACO, Inc. ably provided data programming, compilation, and analysis, as well as assisting with sonobuoy modifications. Kim Fearon and Peter Johnsen of SEACO, Inc. patiently listened to the endless hours of acoustic recordings and assisted with data analysis. Richard Sugiyama of SEACO, Inc. and the graphics department of NOSC assisted in compiling graphic arts. We thank Bob Evans, Steve Johnson, Gary Miller, and John Richardson of LGL Limited, and John Ford, Lois Harwood, and Pam Norton of Environmental Sciences Limited for their cooperation, during and after the field season, in compiling aerial survey data from additional projects. Special thanks to Gloria Young of SEACO, Inc. for typing numerous drafts of the manuscript and assisting in its compilation.

MA

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:

3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S): NOSC TR 1177

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: Naval Ocean Systems Center

6b. OFFICE SYMBOL (if applicable): Code 514

7a. NAME OF MONITORING ORGANIZATION:

6c. ADDRESS (City, State and ZIP Code): Biological Sciences Branch, San Diego, CA 92152-5000

7b. ADDRESS (City, State and ZIP Code):

8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Minerals Management Service, Department of Interior

8b. OFFICE SYMBOL (if applicable): DOI-733

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: OCS Study: MMS 87-0039

8c. ADDRESS (City, State and ZIP Code): Washington, DC 20240

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	AGENCY ACCESSION NO
FGOV	MMS	514-MM25	DN988 579

11. TITLE (include Security Classification): Distribution, Abundance, Behavior, and Bioacoustics of Endangered Whales in the Alaskan Beaufort and Eastern Chukchi Seas, 1979-86

12. PERSONAL AUTHOR(S): D.K. Ljungblad (NOSC), S.E. Moore, J.T. Clarke, and J.C. Bennett (SEACO Inc.)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM Aug 86 TO Oct 86	July 1987	391

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Endangered Whales, Alaska, North Slope, Chukchi and Beaufort Seas, Migration, Population, Habitat, Behavior, Density

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Aerial surveys and acoustic recordings of bowhead whales and, secondarily, other marine mammals were made from mid-August 1986 through October 1986 in the eastern Chukchi and Alaskan Beaufort Seas. In addition, a shore-based acoustic station was established on Barter Island, Alaska to record the calls of migrating bowhead whales as they passed through the eastern Alaskan Beaufort Sea. Survey results and observations on bowhead whale distribution, relative abundance and density, migration patterns, general behavior, and sound production are presented. Presented here also are survey results and observations on gray whale distribution, relative abundance, and general behavior. Incidental sightings of all marine mammals are reported.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: D.K. Ljungblad

22b. TELEPHONE (include Area Code): (619)225-2359

22c. OFFICE SYMBOL: Code 514

DD FORM 1473, 84 JAN

83 APR EDITION MAY BE USED UNTIL EXHAUSTED
ALL OTHER EDITIONS ARE OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DD FORM 1473, 84 JAN

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

EXECUTIVE SUMMARY

This report summarizes the 1986 investigations of the distribution, abundance, migration timing, habitat relationships, and behavior of endangered whales in the eastern Chukchi and Alaskan Beaufort Seas. The Western Arctic stock of bowhead whales (*Balaena mysticetus*), estimated by the International Whaling Commission (IWC) to contain 4417 whales, was the principal species studied. Data presented herein were collected during transect and search aerial surveys flown over the study area in a specially modified Grumman Goose from 15 August through 25 October, and in a deHavilland Twin Otter from 7 September through 14 October. Additionally, an acoustic monitoring station was established at Barter Island, Alaska, from 25 August through 11 October. This station augmented the visual data collected via aerial surveys with passively derived acoustic data during the fall bowhead whale migration. Visual data collected during the 1986 study are subsequently compared to the results of previous (1979-85) seasonal efforts.

One hundred and seven sightings of 158 bowhead whales (*Balaena mysticetus*) were made from mid-August through late October in the Alaskan Beaufort and northeastern Chukchi Seas. Survey effort and all bowhead sightings are depicted in daily flight maps and tabularized summaries presented in Appendix A. More bowheads were seen in the latter half of August (n = 41) than for the full month in the two previous years (n = 12, 1985; n = 19, 1984). In August, bowheads were usually seen nearshore between Herschel Island and Demarcation Bay generally feeding. Seventy-nine bowheads were seen in September, similar to numbers seen in 1979 (n = 60), 1980 (n = 34), 1983 (n = 78), and 1985 (n = 67), but far below the numbers seen in 1981 (n = 232), 1982 (301), and 1984 (260). During the first half of September, bowheads were primarily seen north and east of Barter Island. During the latter half of September whales were distributed across the Alaskan Beaufort Sea and into the Chukchi Sea (n = 1 whale). Thirty-eight bowheads were seen in October, primarily in western Alaskan Beaufort Sea and into the northeastern Chukchi Sea (n = 3).

Overall during eight survey seasons (1979-86), 1064 sightings of 1870 bowheads have been made from August through October. In August, bowheads were seen in the eastern Alaskan Beaufort Sea extending as far west as 147°W. In September and October, bowheads were distributed across the Alaskan Beaufort

Sea and their distribution overlapped some Outer Continental Shelf (OCS) oil and gas lease areas within the Beaufort Sea Planning Area. Estimates of bowhead densities for 1979-86 are presented in Appendix B. Overall, highest monthly bowhead densities were calculated for subregion D5 in August (0.435 whales/100 km^2), subregion A2 in September (7.745 whales/100 km^2), and subregion B3 in October (2.033 whales/100 km^2).

The observed 1986 bowhead migration period extended from 7 September to 17 October, a shorter time period than in any year except 1980 (35 days) and 1985 (29 days). Bowheads were seen in the Alaskan Beaufort Sea as early as 16 August, but except for three whales swimming west near the U.S./Canadian demarcation line on 17 August, bowheads seen prior to 7 September did not appear to be migrating. Peak daily abundance indices (WPUE = no. whales/hour of survey effort) during the migration occurred on 25 September (2.21), 28 September (6.01), 6 October (2.32) and 12 October (3.11).

The axis of the 1986 bowhead migration, as defined by median depth at sightings made on random transects, was the 25 m isobath. This axis was similar to that in all other years except 1983, when the median depth at random bowhead sightings during the migration was 145 m ($U = 1289$, $p \leq 0.001$). Peak 5-day SPUE (SPUE = no. bowhead sightings/hour of survey effort) was earlier in years of heavy-ice cover (1980, 1983) than in years of light-ice cover (1979, 1981, 1982, 1984, 1986). The peak 5-day SPUE in 1985, a year of moderate-ice cover due to a mid-September storm, was later (11-15 October) than for any other year. Ice cover was negatively correlated with peak WPUE ($r = -0.746$, $p < 0.05$), and negatively associated with the percentage of whales observed feeding ($r = -0.625$, $p < 0.10$). Ice cover may also limit the ability of observers to see surfaced whales at greater distances from the survey trackline as ice cover was negatively correlated with sighting distance in 1982 ($r = -0.299$, $p < 0.001$) and 1983 ($r = -0.260$, $p < 0.05$), and for the combined data of 1981-86 ($r = -0.174$, $p < 0.001$). The combined data of 1981-86 indicated that bowheads were seen in relatively lighter-ice cover (29%) than overall average ice conditions recorded during random transect surveys (45%; $t' = 5.85$, $p < 0.001$). Bowheads were more often observed involved in social behaviors (56%) than migrating (44%) in 1986, similar to 1982 and 1984. Fewer bowhead calls were recorded on the survey aircraft in 1986 than any year since 1982; however, call rate (no. calls/hour) was higher in 1986 than for any other year.

Eight bowhead calves were seen during fall 1986, resulting in a gross annual recruitment rate (GARR) of 8/158 or 5 percent, the same as that for 1982 and 1985, but higher than all previous years except 1983 (8%).

The acoustic monitoring station recorded over 590 hours of underwater sounds north of Barter Island between 25 August and 11 October. The first bowhead call was heard on 3 September, two more calls were recorded on 9 September and a single call on 11 September. The period of highest calling activity extended from 25 September through 7 October when 6887 bowhead calls were recorded. This period of relatively high bioacoustic activity corresponded with the late September to early October sighting rate (WPUE, SPUE) peaks for the 1986 season.

Fifty-seven sightings of 156 gray whales (Eschrichtius robustus) were made during September and October. Gray whales were usually seen (81%, n = 127) in the Chukchi Sea from 0.5 to 166 km offshore, with the remaining 19 percent (n = 29) seen in the Beaufort Sea. Gray whale distribution was similar to that of past years, with two exceptions: grays were consistently seen farther offshore in the Chukchi Sea, and slightly farther to the east in the Alaskan Beaufort Sea than in other years. Gray whale abundance and density estimates were highest in the offshore blocks in 1986. Additional gray whale density estimates are presented in Appendix B. Most gray whales were feeding (81%, n = 126) or swimming (13%, n = 21), and one group of three was observed mating. One gray whale calf was seen.

Two hundred forty-three sightings of 666 gray whales have been made between August and November since 1980; 323 of these whales were seen between Icy Cape in the Chukchi Sea and Pt. Barrow in the western Beaufort Sea since 1982 when offshore survey coverage in the Chukchi Sea began. The majority of gray whales of the latter data set were seen feeding (81%, n = 263) and were in open water (96%, n = 310) or light (< 20%) ice cover (4%, n = 13).

Groups of belukhas or white whales, some with calves, were seen in the Alaskan Beaufort and northeastern Chukchi Seas throughout the fall. Belukhas were distributed farther offshore in significantly deeper water ($\bar{x}$ = 692.7 m) than bowhead whales ($\bar{x}$ = 50.6 m; t = 7.37, p < 0.001). Two narwhals were seen in the Canadian Beaufort Sea. Walruses, bearded seals, ringed seals, unidentified pinnipeds, and polar bears were seen throughout the fall season. Multiyear reviews of belukha, walrus, bearded seal, ringed seal, and polar bear data are included.

ACRONYMS AND ABBREVIATIONS

ADFG	Alaska Department of Fish and Game
AM	Amplitude Modulated
AMP	A Mapping Package
ASA	American Standards Association
BE	Belukha
BH	Bowhead (Whale)
BS	Bearded Seal
CPUE	Calves Per Unit Effort
CR	Call Rate
CT	Unidentified Cetacean
FM	Frequency Modulated
GARR	Gross Annual Recruitment Rate
GNS	Global Navigation System
GW	Gray Whale
IDL	International Date Line
IWC	International Whaling Commission
MMS	Minerals Management Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NOSC	Naval Ocean Systems Center
NTIS	National Technical Information Service
OCS	Outer Continental Shelf
PN	Unidentified Pinniped
PR	Polar Bear
RS	Ringed Seal
s.d.	Standard Deviation
SPUE	Sightings Per Unit Effort
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VHF	Very High Frequency
WPUE	Whales Per Unit Effort
WS	Walrus

CONTENTS

Page

FIGURES

Page

Page

TABLES

Page

INTRODUCTION

The Naval Ocean Systems Center (NOSC), San Diego, California, has been funded by the Alaska Outer Continental Shelf (OCS) area office of the Minerals Management Service (MMS), U.S. Department of the Interior, since 1979 to conduct aerial surveys of endangered whales and other marine mammals in the northern Bering (above 63°N), eastern Chukchi, and Alaskan Beaufort Seas. As part of its responsibilities under the OCS Lands Act, National Environmental Policy Act, Marine Mammal Protection Act, and Endangered Species Act, MMS has continued this work as an extension of previous studies (Ljungblad et al., 1980; Ljungblad, 1981; Ljungblad et al., 1982a, 1983, 1984a, 1985a, 1986b). Results of these studies have been useful to MMS in preparing environmental impact statements and in making decisions relative to the leasing, exploration, and development of the Alaskan OCS.

The bowhead whale (Balaena mysticetus) has been the principal species investigated over the past 8 years. Historically, bowheads had a nearly circumpolar distribution north of 60°N. However, a long history of exploitation seriously reduced the number of whales in each of five geographically separate stocks (Breiwick et al., 1981; Bockstoce and Botkin, 1983; Bockstoce, 1986). The Western Arctic stock, estimated by the International Whaling Commission (IWC) to contain 4,417 whales (IWC, 1986), is the population monitored in this study. This stock annually migrates around western and northern Alaska between wintering areas in the northern Bering Sea and summer feeding grounds in the Canadian Beaufort Sea. The spring migration generally occurs along open-water lead systems that annually develop relatively nearshore in the Chukchi Sea, but offshore and well north of oil exploration activities in the Alaskan Beaufort Sea (Braham et al., 1984; Ljungblad et al., 1986c). During the autumn migration, however, bowheads commonly occur nearshore within or near oil lease areas in the Alaskan Beaufort Sea. Because of this, the MMS has continued to monitor the annual progress and potential interaction of the fall bowhead migration in relation to ongoing oil exploration activities.

The distribution, relative abundance, and behavior of gray whales (Eschrichtius robustus) have also been investigated during these studies. Principal areas surveyed have been the summer feeding grounds in the northern Bering Sea and eastern Chukchi Sea (Bogoslovskaya et al., 1981; Nerini, 1984; Moore et al.,

1986b), and the northeastern Chukchi Sea (Moore et al., 1986a). This population is now estimated to number 17,577 ± 2,364 whales (Reilly et al., 1983).

This report is a summary of 1986 field results on aerial surveys of bowhead whale distribution, relative abundance, density, migration, and behavior in accordance with the objectives outlined below. To augment visual information derived from aerial surveys, an acoustic station was established in the eastern Alaskan Beaufort Sea during the 1986 field season in an effort to monitor the fall bowhead migration via passive acoustics. Acoustic studies conducted during the spring bowhead migration have provided enhanced descriptions of whale distribution, movements, and habitat relationships (Clark, 1983; Clark et al., 1985; Clark et al., 1986; Cummings and Holliday, 1983). The results of the acoustic monitoring efforts are presented and integrated with aerial survey sightings as appropriate. Gray whale distribution, relative abundance, density, habitat relationships, and behavior are also reported, as well as incidental information on all other marine mammals seen. Flight tracks and descriptive captions presented in Appendix A provide an overview of daily survey efforts and results.

Objectives

The primary objectives of the 1986 aerial surveys were to

- o determine seasonal distribution, migration routes, relative abundance, and habitat characteristics of endangered whales in or near existing and proposed Federal lease sales in the eastern Chukchi and Alaskan Beaufort Seas;
- o derive estimates and indicators of relative and/or absolute abundance of endangered whales in these areas;
- o describe behavioral characteristics of endangered whales observed in these areas;
- o deploy sonobuoys to detect sounds produced by whales, to be used as additional indices of whale presence in these areas;
- o monitor the daily status of the bowhead whale migration across the Alaskan Beaufort and eastern Chukchi seas and describe the general behavior and sound production of observed whales;
- o summarize daily survey efforts, bowhead sightings, and behavior, and survey conditions from additional MMS-funded and industry-funded projects, and reformat to NOSC-format data files;

- collate bowhead distribution, behavior, movement, and habitat relationship data from all projects and provide comprehensive daily reports from the field base of operations via phone modem to the Anchorage MMS office. These reports were subsequently provided to the Government officials responsible for regulating offshore drilling and geophysical exploration, and for protecting endangered species (Minerals Management Service and National Marine Fisheries Service, respectively);
- obtain distributional information on nonendangered marine mammals incidental to other investigations;
- consult and coordinate field activities with other Federal agencies, state or local government organizations, or other endangered species researchers to maximize productivity of this study and minimize conflict with other resource uses;
- synthesize and further analyze data obtained during the 1979-86 period of investigation.

In conjunction with the primary objectives, an acoustic station was established north of Barter Island, Alaska to monitor the occurrence of bowhead whales in the eastern Alaskan Beaufort Sea via passive acoustics. Specific objectives of the acoustic station were to

- detect the temporal occurrence of bowhead whales in the eastern Alaskan Beaufort Sea via passive acoustic techniques;
- correlate recorded bowhead bioacoustic data with visual sighting data provided by personnel conducting aerial surveys over waters near Barter Island;
- record and classify ambient and industrial noise off Barter Island as possible.

In addition to these objectives, aerial surveys were conducted in support of satellite and radiotelemetry-tagging studies. Most flights were conducted between Kay Point and Komakuk Beach (approximately 138°W to 140°W) over nearshore Canadian waters in support of efforts to attach a satellite transmitter package to a bowhead whale. A comprehensive report of these efforts and their results is provided in Mate (1987).

METHODS AND MATERIALS

Project Rationale and Design

The proposed field schedule was designed to (a) maximize information on the distribution, movements and behavior of bowhead whales from mid-August through early September; (b) monitor the progress of the bowhead migration across the Alaskan Beaufort Sea from September through mid-October; and (c) determine when bowheads entered the eastern Chukchi Sea in September and October. Secondarily, the distribution, abundance, and behavior of gray whales were studied in the eastern Chukchi Sea in September and October. Two survey aircraft, a land-based acoustic monitoring station, and a field-computing station were required to meet study objectives. Bases of operation were Barrow, Deadhorse, and Barter Island, Alaska (Table 1).

Comprehensive aerial surveys were flown in a modified Grumman Goose (N780) in the Alaskan Beaufort and eastern Chukchi Seas to provide broad scale survey coverage and baseline sighting data, and to complement the efforts of additional MMS-funded studies. Surveys conducted during the latter half of August were directed toward the eastern Alaskan Beaufort Sea to assess ice conditions and bowhead distribution and behavior. These data were forwarded to researchers conducting an MMS-sponsored bowhead feeding study in this area during September (Richardson, 1987). In September and October, surveys were conducted primarily in the eastern Chukchi Sea, with occasional surveys in the western Beaufort Sea, to assess bowhead and gray whale distribution and abundance and document the timing of the bowhead migration through these waters.

Aerial surveys to assess the status of the fall bowhead migration were flown in a deHavilland Twin Otter (302EH) near areas of industrial activity. Daily information on bowhead distribution, movements, and behavior near industrial operations during the westward migration across the Alaskan Beaufort Sea was sought by MMS in order to implement permit regulations for industrial operations. Prior to and during the start of the fall migration, logistic support was provided via 302EH to researchers conducting an MMS-sponsored satellite and VHF-tagging project in Canadian waters (Mate, 1987; Richardson, 1987).

The acoustic monitoring station established at Barter Island consisted of a field laboratory where underwater acoustic data transmitted from a single-hydrophone sonobuoy moored approximately 5 km offshore were monitored and

- o collate bowhead distribution, behavior, movement, and habitat relationship data from all projects and provide comprehensive daily reports from the field base of operations via phone modem to the Anchorage MMS office. These reports were subsequently provided to the Government officials responsible for regulating offshore drilling and geophysical exploration, and for protecting endangered species (Minerals Management Service and National Marine Fisheries Service, respectively);
- o obtain distributional information on nonendangered marine mammals incidental to other investigations;
- o consult and coordinate field activities with other Federal agencies, state or local government organizations, or other endangered species researchers to maximize productivity of this study and minimize conflict with other resource uses;
- o synthesize and further analyze data obtained during the 1979-86 period of investigation.

In conjunction with the primary objectives, an acoustic station was established north of Barter Island, Alaska to monitor the occurrence of bowhead whales in the eastern Alaskan Beaufort Sea via passive acoustics. Specific objectives of the acoustic station were to

- o detect the temporal occurrence of bowhead whales in the eastern Alaskan Beaufort Sea via passive acoustic techniques;
- o correlate recorded bowhead bioacoustic data with visual sighting data provided by personnel conducting aerial surveys over waters near Barter Island;
- o record and classify ambient and industrial noise off Barter Island as possible.

In addition to these objectives, aerial surveys were conducted in support of satellite and radiotelemetry-tagging studies. Most flights were conducted between Kay Point and Komakuk Beach (approximately 138°W to 140°W) over nearshore Canadian waters in support of efforts to attach a satellite transmitter package to a bowhead whale. A comprehensive report of these efforts and their results is provided in Mate (1987).

METHODS AND MATERIALS

Project Rationale and Design

The proposed field schedule was designed to (a) maximize information on the distribution, movements and behavior of bowhead whales from mid-August through early September; (b) monitor the progress of the bowhead migration across the Alaskan Beaufort Sea from September through mid-October; and (c) determine when bowheads entered the eastern Chukchi Sea in September and October. Secondarily, the distribution, abundance, and behavior of gray whales were studied in the eastern Chukchi Sea in September and October. Two survey aircraft, a land-based acoustic monitoring station, and a field-computing station were required to meet study objectives. Bases of operation were Barrow, Deadhorse, and Barter Island, Alaska (Table 1).

Comprehensive aerial surveys were flown in a modified Grumman Goose (N780) in the Alaskan Beaufort and eastern Chukchi Seas to provide broad scale survey coverage and baseline sighting data, and to complement the efforts of additional MMS-funded studies. Surveys conducted during the latter half of August were directed toward the eastern Alaskan Beaufort Sea to assess ice conditions and bowhead distribution and behavior. These data were forwarded to researchers conducting an MMS-sponsored bowhead feeding study in this area during September (Richardson, 1987). In September and October, surveys were conducted primarily in the eastern Chukchi Sea, with occasional surveys in the western Beaufort Sea, to assess bowhead and gray whale distribution and abundance and document the timing of the bowhead migration through these waters.

Aerial surveys to assess the status of the fall bowhead migration were flown in a deHavilland Twin Otter (302EH) near areas of industrial activity. Daily information on bowhead distribution, movements, and behavior near industrial operations during the westward migration across the Alaskan Beaufort Sea was sought by MMS in order to implement permit regulations for industrial operations. Prior to and during the start of the fall migration, logistic support was provided via 302EH to researchers conducting an MMS-sponsored satellite and VHF-tagging project in Canadian waters (Mate, 1987; Richardson, 1987).

The acoustic monitoring station established at Barter Island consisted of a field laboratory where underwater acoustic data transmitted from a single-hydrophone sonobuoy moored approximately 5 km offshore were monitored and

Table 1. Proposed field schedule, 1986.

TASK	PURPOSE	DATES	EFFORT		BASE
Comprehensive Aerial Surveys (a/c: Grumman Goose, N780)	a) bowhead feeding study support	15-31 Aug	55h:bks.	4-9	Deadhorse
	b) bowhead and gray whale distribution and abundance	1-30 Sep 1-25 Oct	110h:bks 90h:bks.	W12-22 3, 11, 12-22	Barrow
Aerial Surveys to Assess Migration Status (a/c: Twin Otter, 302EH)	a) support satellite tagging project	27-31 Aug	15h:CAN		Deadhorse
	b) provide information pertinent to seasonal drilling restrictions and support tagging project	1-30 Sep	90h:bks.	1, 2, 4-10 and CAN	Deadhorse
	c) support radio telemetry	1-15 Oct	45h:bks.	1-11	Deadhorse
Acoustic Monitoring	a) determine bowhead presence acoustically	15 Aug - 15 Oct	block	4	Barter Is.
Computer Transfer of Sighting Data	a) provide information pertinent to implementation of seasonal drilling restriction	30 Aug 15 Oct	--		Deadhorse

recorded. The intent of the acoustic station was to continuously monitor the coastal waters of the eastern Alaskan Beaufort Sea for bowhead calls to be used as an index of whale presence and movement into the area. This daily acoustic information supplemented visual data obtained by aerial surveys and extended monitoring efforts overnight and through periods of inclement weather when surveys could not be flown.

A daily transfer of flight track maps depicting bowhead sightings (see Appendix A) was accomplished via phone modem link between computer stations established at Deadhorse and at MMS headquarters in Anchorage. A text summary of sighting data from all bowhead researchers, as well as a notation on data from the acoustic station, accompanied the survey map. These daily data transfers were supplemented by telephone reports during the bowhead migration. This daily transfer of information facilitated MMS decision making regarding implementation of lease stipulations and permit regulations.

Aerial Surveys in the Alaskan Beaufort and Eastern Chukchi Seas

As in past years, aerial surveys provided the primary means of acquiring data on the distribution, movements and behaviors of bowhead whales during the fall migration. These data were subsequently incorporated into the 7-year NOSC data base.

Study Area and Aerial Survey Procedures

The aerial survey study area included the Alaskan Beaufort Sea from 157°W east to 140°W offshore to 72°N, and the eastern Chukchi Sea from 157°W west to the International Data Line (IDL, approximately 168°58'W) between 68°N and 72°N. This area was divided into survey blocks (Figure 1) suitable to line transect surveys (one or, with favorable conditions, two blocks could be surveyed completely on one flight). The Alaskan Beaufort Sea comprised blocks 1 to 12 and the eastern Chukchi Sea blocks 13 to 22.

Two types of aerial surveys were utilized to accomplish the listed objectives:

1. Line transect surveys were flown in survey blocks to determine distribution and estimate relative and absolute abundance. Line transect is one available survey method from which statistical inferences can be made, provided the starting and turning points of the line are selected randomly (Cochran, 1963). Survey blocks were divided into sections that were 30 minutes of longitude or 10 minutes of latitude wide, and each section divided into 10 equal segments. Starting and/or turning points were chosen within each section by selecting two numbers from a random numbers' table and matching them to the numbered segments. A transect line was then drawn between the two segments. The same procedure was followed for each section of the survey block, and all transect lines were then linked together with connecting lines at top and bottom. When bowheads were encountered while surveying a transect line, the aircraft diverted from transect for brief periods ($\leq$ 10 min) and circled the whales to observe behavior, obtain better estimates of their numbers, and determine whether calves were present. Only bowheads seen initially before diverting from the transect line were included in density calculations.

2. Search surveys were flown to locate whales and observe their behavior or when in transit to a transect block or a new base of operations. These surveys did not follow a preset paradigm, but instead were dependent upon weather, sea state, and ice conditions, or our previous patterns of whale sightings.

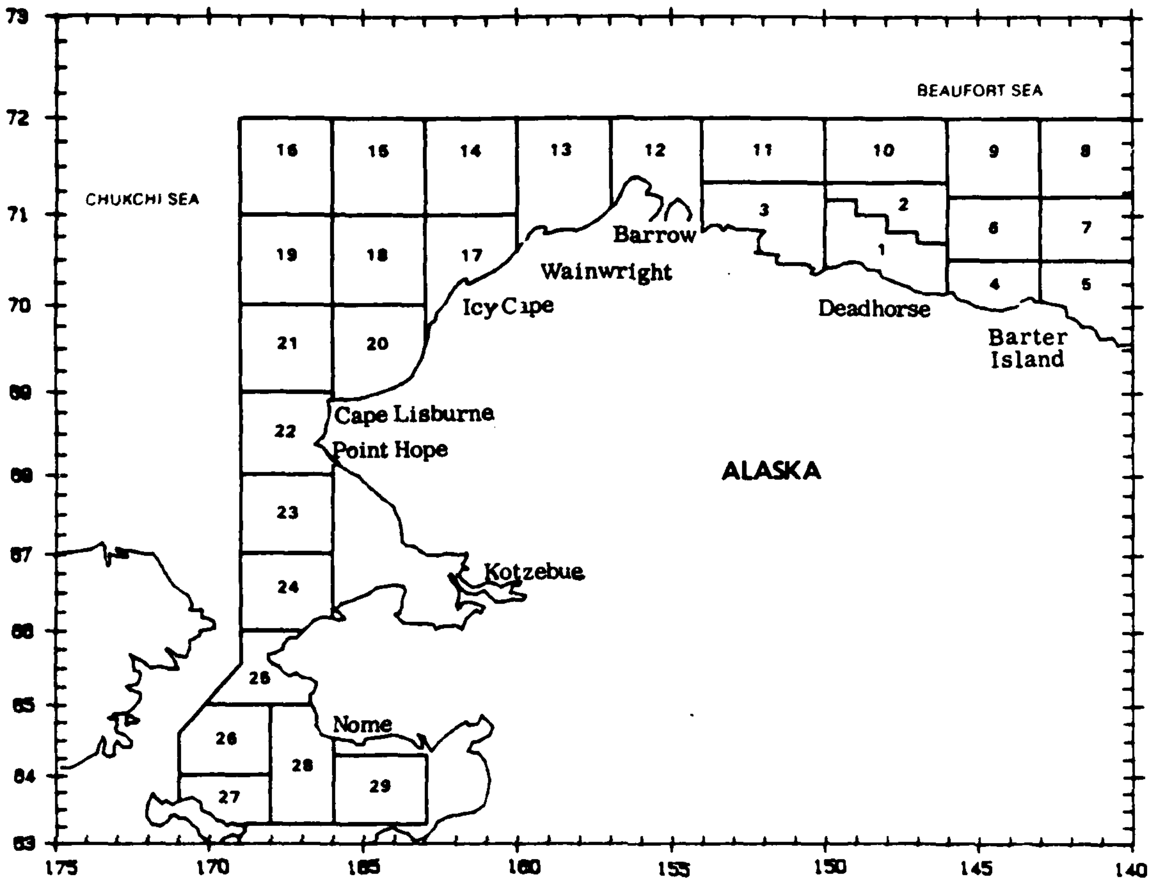


Figure 1. Aerial survey study area and transect blocks.

Equipment, Data Collection, and Analyses

The two aircraft used for the surveys were a Grumman Turbo Goose model G21G with a call sign of N780, and a deHavilland Twin Otter series 300 with a call sign of 302EH. Both aircraft were equipped with a Global Navigation System (GNS) 500 that provided continuous position updating (0.6 km/survey hour, precision) and transect turning point programming. Surveys were flown at 100-m to 458-m altitude, at speeds of 222 to 296 km/hr. The higher altitudes were maintained when weather permitted in order to maximize visibility and to minimize disturbance to marine mammals. The Grumman's maximum time aloft was 6.5 hours and the Twin Otter's was 8 hours.

The Grumman Goose cockpit was outfitted with four seats, each of which afforded excellent visibility through large side windows for the two principal observers and pilots. A long rectangular window behind the cockpit provided good visibility for the observer-recorder. The Twin Otter was equipped with bubble windows aft for an observer and an observer-recorder. A third observer-navigator

occupied the copilot seat and was afforded good forward and side viewing from that position. Each observer had a clinometer to take angles on all whale sightings abeam of the aircraft which, along with altitude, can be used to compute animal distance from the survey track line. Observers and pilots were linked to a common communication system, and commentary on the aircraft could be recorded.

A portable computing system (Hewlett-Packard 85) was used aboard each aircraft to store and later analyze flight data. The computer was interfaced to the Global Navigation System (GNS) for automatic input of entry number, time, latitude and longitude, and to the radar altimeter for precise input of altitude. One of four different data entry formats was selected on the computer depending on the reason for entry. Whenever possible, a 28-key entry format was used when whales were seen (Table 2). An abbreviated 20-key sighting update format was used when several whales were sighted within a short period of time. An even shorter rapid sighting update (9-key format) was used in areas of extremely high animal concentrations to avoid the lumping of sightings. A position update 13key format, including data on weather, visibility, ice cover, and sea state, was entered at turning points, when environmental conditions changed, or, in the absence of sighting data, every 10 minutes. All entries were coded as to the type of survey being conducted (Table 2: Entry no. 7). During a typical flight (Figure 2), a search leg was flown to the survey block, followed by a series of random transect legs that were joined together by connect legs, with search leg(s) conducted back to the base of operations. Sea state was recorded according to the Beaufort scale outlined in Piloting, Seamanship, and Small Boat Handling (Chapman, 1971). Ice type was identified using terminology presented in the Naval Hydrographic Office Publication Number 609 (1956), and ice cover was estimated in percent.

Sonobuoys are passive listening systems containing a hydrophone and a VHF transmitter. These units were dropped near whales whenever possible in an attempt to record acoustic data. The model AN/SSQ-57A and AN/SSQ-41B sonobuoys, with frequency responses of 10 Hz to 20 kHz, were most commonly used. Sonobuoys are designed to be dropped from aircraft, with their descent slowed by means of a rotochute or parachute. Once in contact with water, the unit is energized by a saltwater-activated battery. At that time the roto/parachute assembly is jettisoned and the hydrophone dropped to a preselected depth of 18.2 or 91.4 m. The 18.2-m depth setting was most commonly

Table 2. Data entry sequence on the portable flight computer.

Position/environmental update (13-key)

1. **Entry number**
2. **Time**
3. **Latitude**
4. **Longitude**
5. **Altitude**
6. **Reason for entry**
7. **Survey type (flag)**
8. Weather
9. Visibility right
10. Visibility left
11. Ice coverage
12. Ice type
13. Sea state
14. Water color
15. Water depth
16. **Species**
17. Clinometer angle
18. Sighting cue
19. Behavior
20. **Total number**
21. Estimated size class
22. Total number calves
23. Swim direction
24. Estimated swim speed class
25. Response to aircraft
26. Repeat sighting
27. Photo roll number
28. Photo frame numbers

Sighting update (20-key)

Rapid sighting update (9-key)

---

used. The sounds picked up by the hydrophone are amplified and transmitted to a VHF broadband receiver aboard the aircraft. The receiver output was recorded on a Nagra IV SJ recorder with a frequency response within 2 dB from 25 Hz to 10 kHz, at a recording speed of 9.5 cm/s. This recorder has two channels, permitting simultaneous recording of waterborne sounds and observers' verbal comments.

Attempts were made to photograph bowhead whales whenever possible. Still photographs were made with hand-held 35-mm cameras (Olympus OM-1) with 210-mm or 230-mm lenses using ASA 64 or ASA 200 film at as fast a shutter speed as possible. The altitude of the aircraft and the photograph roll and frame number were noted and stored on the computer.

Observed bowhead distribution was plotted semimonthly in relation to OCS oil and gas lease areas within the Beaufort Sea Planning Area. In addition, comprehensive bowhead distribution analysis was compiled from the daily sighting

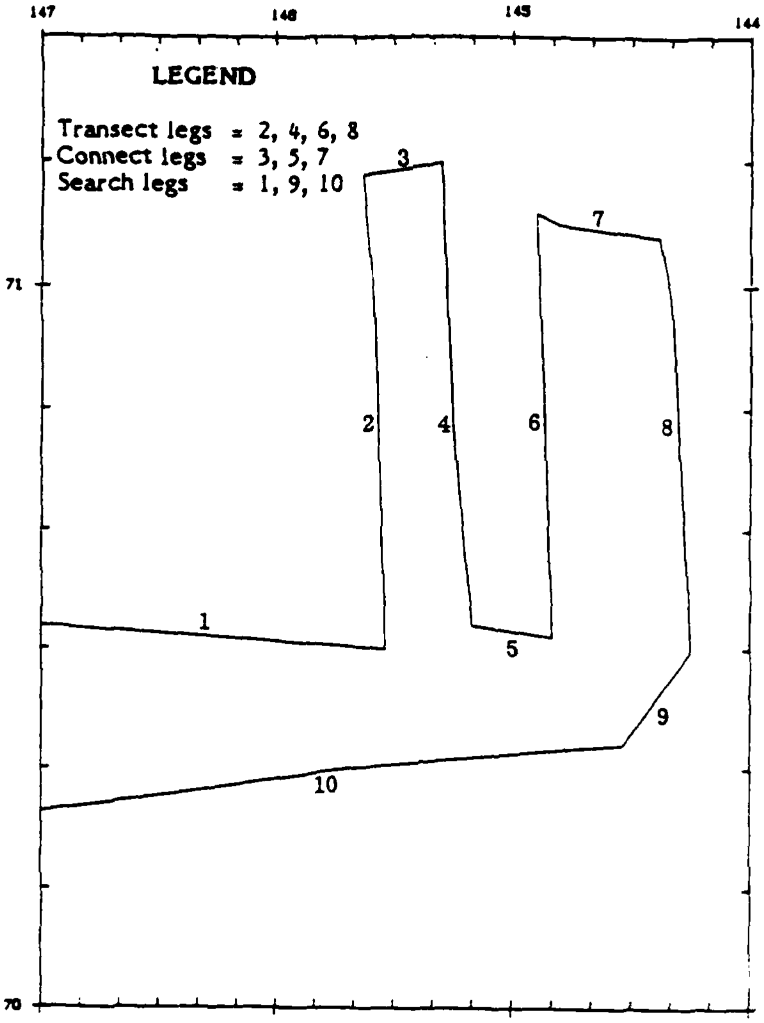


Figure 2. Example of aerial survey flight track delineating transect, connect, and search survey legs.

summaries of six survey aircraft. These data were plotted, as appropriate, to depict bowhead distribution in relation to OCS drilling sites that were active in 1986.

An index of relative abundance was derived as whales per unit effort (WPUE = no. whales/hours of survey effort) per survey block for bowhead, gray and belukhas. Bowhead and gray whale density estimates were derived for survey blocks using strip transect methodologies (Estes and Gilbert, 1978). All whale sightings were entered into the distribution and relative abundance analyses, regardless of the type of survey leg being conducted when the sighting was made. Therefore, distribution scattergrams and WPUE represent the total bowhead sighting data base in relation to the total survey effort. Density estimates, on the

other hand, require that sightings used in their derivation be collected at random (Cochran, 1963). Therefore, only sightings made on random transect legs were used to derive density estimates; if no sightings were made on random transects within a survey block, density was not calculated for that block. In addition to the survey block analysis, density estimates were also derived for subregions reflecting bathymetrically stratified OCS lease sale planning areas and are presented, with a description of density estimate methodologies, in Appendix B.

The timing of the 1986 migration across the Beaufort Sea was analyzed as sightings per unit effort (SPUE = no. sightings/hours of survey effort) and WPUE/date. Habitat preference was depicted as percentage of whales/ice class and percentage of whales/depth regime. Directionality of whale headings was analyzed using Rayleigh's test (Batschelet, 1972). The 1979-86 bowhead sighting data base was analyzed for potential shifts in migration route, as defined by water depth at random bowhead sightings, via Mann-Whitney U comparisons. Changes in migratory timing and median water depth at random bowhead sightings in relation to concomitant ice cover was analyzed via regression analysis. The annual timing of the 1979-86 bowhead migrations was analyzed as SPUE per 5-day periods, from August through October. The percentage of ice cover was averaged over 5-day periods and compared to the SPUE by regression analysis. The probability of detecting bowheads during the 1979-86 fall migrations was estimated by analyzing the effect of surface conditions (i.e., ice cover and sea state) on the sighting distance of surfaced bowheads from the survey track line, and by calculating the probability that a whale will be at the surface and within an observer's field of view after the methodology outlined in Davis et al. (1982). Additional statistical comparisons, correlations, and regressions were performed as appropriate (Zar, 1984).

Bowhead behaviors were classified by means of operational definitions (Table 3). Behaviors were grossly catalogued into two types for purposes of discussion: migratory behaviors, including swimming and diving; and social behaviors (typically observed in groups) such as milling, feeding, mating, cow-calf association, resting, and displaying. Displays included breaches, spy-hops, tail and flipper-slaps, rolls, and underwater blows. Swimming speed was subjectively estimated by observing the time it took a whale to swim one body length. An observed swimming rate of one body length/min corresponded to an estimated speed of 1 km/hr, one body length/30s was estimated at 2 km/hr, and so on.

Table 3. Operational definitions of observed bowhead whale behaviors.

MIGRATORY:	
Swimming	Forward movement through the water propelled by tail pushes.
Diving	Change of swimming direction or body orientation relative to the water surface resulting in submergence; may or may not be accompanied by lifting of the tail out of the water.
SOCIAL:	
Milling	Whales swimming slowly near one another in close proximity (within 100 m) at the water surface.
Feeding	Whale/whales diving repeatedly in the same general area sometimes accompanied by mud streaming from the mouth and defecation upon surfacing; nearly synchronous diving and surfacing have been noted as have echelon formation surface feeding with swaths of clearer water noted behind the whales and open mouth surface swimming.
Mating	Ventral-ventral orientation of a pair of whales often with at least one other whale present to stabilize the mating couple; often within a group of milling whales; pairs appear to hold each other with their pectoral flippers and may entwine their tails.
Cow-Calf	Calf nursing; calf swimming within 20 m of an adult.
Resting	Whale/whales at the surface with head, or head and back exposed, showing no movement; more commonly observed in heavy-ice conditions than in open water.
Displaying:	
Rolling	Whale rotating on longitudinal axis, sometimes associated with mating.
Flipper-Slapping	Whale on its side striking the water surface with its pectoral flipper one or many times; usually seen in groups, sometimes when slapping whale is touching another whale.
Tail-Slapping	Whale hanging horizontally or vertically in the water with tail out of water waving back and forth striking the water surface; usually seen in groups.
Spy-Hopping	Whale rising vertically from the water such that the head and up to one-third of the body, including the eye, is exposed.
Breaching	Whale exiting vertically from the water such that half to nearly all of the body is exposed then falling back into the water, usually on its side, creating a large splash and presumably some sounds.
Underwater Blow	Exhalation of breath while submerged creating a visible bubble.

Swimming speed and whale size were recorded by relative category (i.e., still, 0 km/hr; slow, 0-2 km/hr; medium, 2-4 km/hr; or fast, > 4 km/hr; and calf, immature, adult, or large adult respectively) rather than on an absolute scale.

In compliance with condition B.4-6 of permit No. 459 to "take" endangered marine mammals, any sudden overt change in whale behavior observed coincident with the arrival of the survey aircraft was recorded (and later reported) as "response to aircraft," although it was impossible to determine the specific stimulus for the behavioral change. Such changes included abrupt dives, sudden course diversion or cessation of behavior ongoing at first sighting.

Acoustic Monitoring in the Eastern Alaskan Beaufort Sea

An additional task undertaken by NOSC in 1986 was the establishment of an acoustic monitoring station on Barter Island to assess the feasibility of using passive acoustics to detect passing bowhead whales during the westward fall migration. The overall goal of the acoustic station was to stay operational on a 24-hour basis throughout the migration period and to integrate the acoustic data obtained with aerial survey data, whenever possible. Acoustic monitoring provided an independent means of detecting bowheads and expanded the data base by extending data gathering through periods of darkness and bad weather when aerial surveys could not be conducted. An abbreviated summary of acoustic terms is provided to acquaint readers who are not acousticians with the terminology used in this report (Table 4).

Study Area and Acoustic Monitoring Procedures

Barter Island was selected as the monitoring station site because it represented the easternmost location along the bowhead migratory corridor where logistic support was available. The area monitored by the acoustic station extended roughly from the north shore of Barter Island (approx. 70°08'N, 143°40'W) to 70°16'N between 143°20'W and 143°55'W (Figure 3). This area describes an approximate 10-km radius around the position of the moored sonobuoy (70°10.6'N, 143°38'W), and represents the conservative radial limits of the monitoring station based upon the Cummings and Holliday (1983) estimate of bowhead call signal/noise ratio approaching zero at a median distance of 10 km. A 20-km radius around the sonobuoy was considered a secondary zone in which calling bowheads would likely be detected based upon their ability to produce sounds with estimated source levels of 189 dB (Cummings and Holliday, 1983) to 190 dB (Ljungblad and Moore, 1982), and possibly as high as 196 to 200 dB based on a received level of 156 dB at

Table 4. An abbreviated summary of acoustic terminology.

Ambient noise: background noise that does not have an identifiable source. Ambient noise sources include tides and waves, naturally occurring seismic activity, oceanic turbulence, thermal noise, distant ship traffic, and distant biological noise.

Broadband level: the mean square pressure level of a signal in a wide (with reference to 1 Hz) frequency band. A broadband level is the result of integrating spectrum levels over the frequency band of interest.

Cylindrical spreading: the proportional attenuation of sound intensity with distance that is described in dB as 10 log (R_2/R_1) where R_1 is the reference distance. The resultant attenuation rate is 3 dB per distance doubled. Cylindrical spreading is generally assumed when the sound source and receiver are far apart compared to water depth.

Decibel (dB): a logarithmic-scale unit used to describe sound pressure levels. Sound pressure level in dB is defined as $\log_{10}$ (P_2/P_1) where P_2 is the pressure of interest and P_1 is the reference pressure.

Hertz (Hz): a unit of frequency equal to one cycle per second. When frequency exceeds 1000 cycles per second it is denoted as kilohertz (kHz).

Narrowband components: a signal component that has a very small frequency bandwidth compared to the resolution bandwidth of the spectrum analyzer. Such components are often called tones or tonals.

Received level: the intensity or power of a signal at the hydrophone or transducer of interest. With reference to the sonar equation, received level (RL) may be derived as RL = SL - TL.

Signal: the sound of interest.

Sonar equation: an equation that defines transmission loss as the difference in dB between a signal's source level and its received level at some reference distance (usually 1 m or 1 yd). The equation is commonly written as:

Source Level (SL) - Received Level (RL) = Transmission Loss (TL)

All terms in the sonar equation may vary with frequency and direction from the source.

Source level: the intensity or power of a sound source described in dB at some short reference distance (usually 1 m or 1 yd). Source levels often provide only an idealized model of sound intensity as they are often calculated from sound measurements taken at distances > 1 m using an assumed transmission loss factor. With reference to the sonar equation, source level (SL) may be calculated as SL = RL + TL.

Spectrum level: the mean square pressure expressed as dB referred to 1 micro Pascal squared per Hz ($1 \mu Pa^2/Hz$).

Spherical spreading: the proportional attenuation of sound intensity with distance that is described in dB as 20 log (R_2/R_1) where R_1 is the reference distance. The resultant attenuation rate is 6 dB per distance doubled. Spherical spreading is generally assumed when the sound source and receiver are proximate compared to water depth.

Transmission loss: the attenuation of a signal's intensity or power with distance. Transmission loss is generally described by cylindrical or spherical spreading loss models, and occasionally as a combination of the two (i.e., 15 log R_2/R_1: Grachev, 1983). With reference to the sonar equation, transmission loss (TL) may be derived as TL = SL - RL.

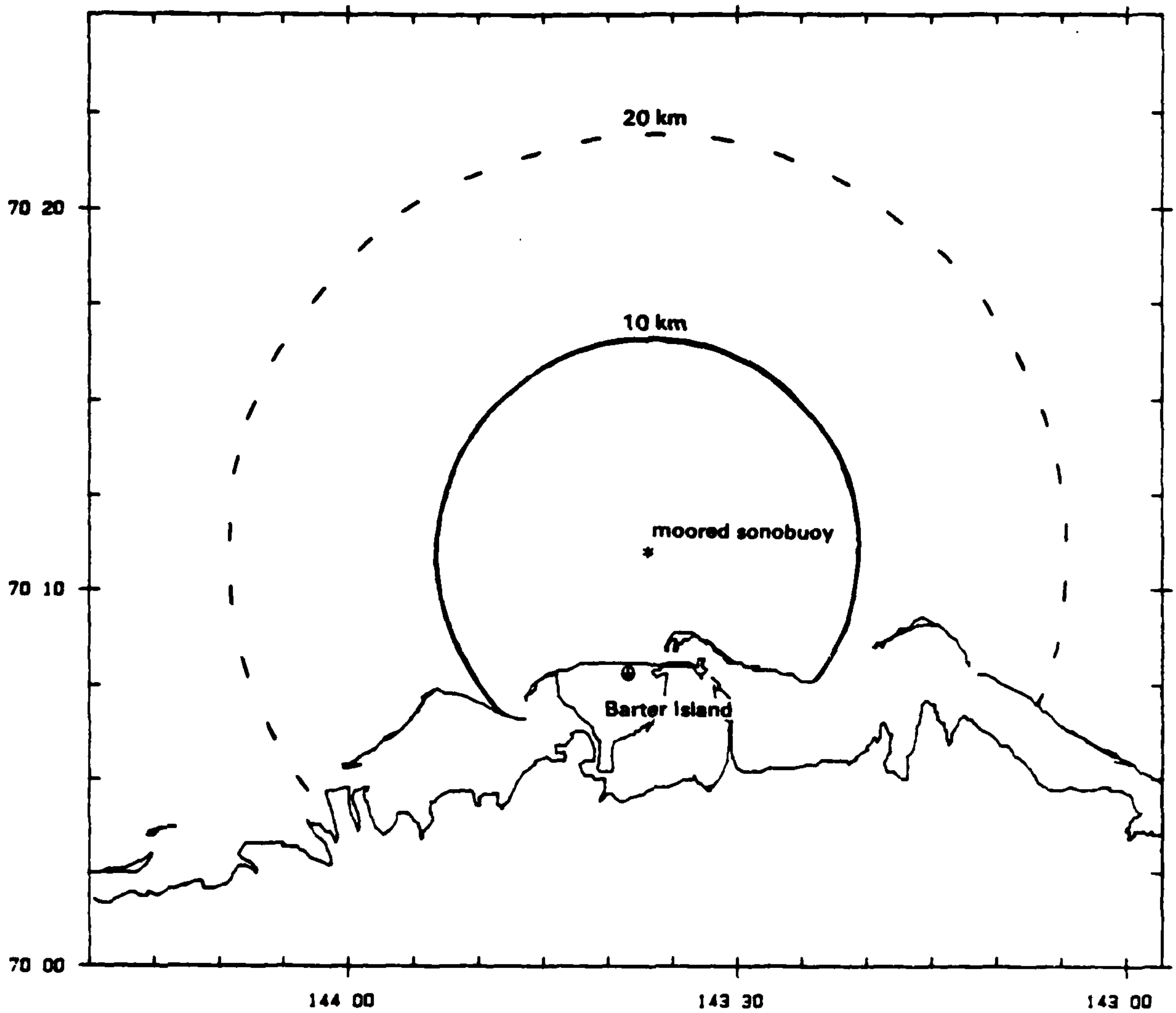


Figure 3. Acoustic monitoring study area depicting shore station (●), location of moored sonobuoy (*) and 10-km and 20-km proposed radial limits of hydrophone reception.

100-150 m (Clark and Johnson, 1984). The 20-km radial distance extended the boundaries of the acoustic study area to roughly 70°22'N between 143°05'W and 144°10'W. Although bowhead calls with a median source level of 193 dB re 1 μPa could theoretically be detected at ranges greater than 20 km, local variation in ambient noise levels and practical experience in recording bowhead sounds via sonobuoys since 1979 deemed it unlikely.

Continuous recordings of the underwater acoustic environment were made whenever the moored sonobuoy was operational. Because the sonobuoys were sometimes destroyed by sea ice and storms, or were low on power, there were

intermittent periods during the study when the unit was off line. A replacement unit was installed by the acoustic station crew as soon as sea conditions permitted. The 24-hour acoustic recordings were augmented by a written daily log describing local weather conditions and notations on industrial and biological sounds heard.

Study Design and Logistics

The acoustic monitoring effort was designed as a simple feasibility study. The study design included the development and deployment of sonobuoys modified to accept external power and the establishment of a shore-based receiving and listening station on Barter Island, which has a well-maintained airstrip and living accommodations. Storage space was also available for replacement sonobuoy systems, mooring equipment, a small inflatable boat with outboard engine and a support vehicle. This type of logistical support proved instrumental to the success of the study.

The shallow nature of the Beaufort Sea shelf near Barter Island imposed some restrictions on the positioning of the sonobuoy's listening hydrophone. A minimum water depth of 8 m was necessary because hydrophone placement must be deeper than one-quarter the wavelength of the lowest frequency being recorded (approx. 50 Hz for bowhead calls) to minimize surface transmission loss. To minimize bottom transmission loss, mid-depth hydrophone placement was desired, therefore a water depth of at least 16 m was considered optimum. Additional considerations relative to the deployment site included the approximate 5-km broadcast limitations of sonobuoy units, the requirement that the site be referenced by landmarks such that the mooring could be relocated from a small boat, and the anticipated storms and ice incursion common to Barter Island in fall (La Belle et al., 1983).

Water depth and potential climatic constraints led to the development of a sonobuoy system designed to be moored in approximately 20 m of water and able to radiotelemeter data to the shore station. Specially modified sonobuoys provided a cost-effective system that could be left in place during unfavorable sea conditions and be easily replaced as necessary by additional systems warehoused at the shore station. A hard-wired hydrophone system would have required an expensive underwater cable with multiple preamplifiers over 4 kilometers in length in order to reach water sufficiently deep enough to receive bowhead calls. Permanent moorings or fixed hydrophone stations would be difficult to protect from ice and weather conditions without a great deal of expense and logistical support.

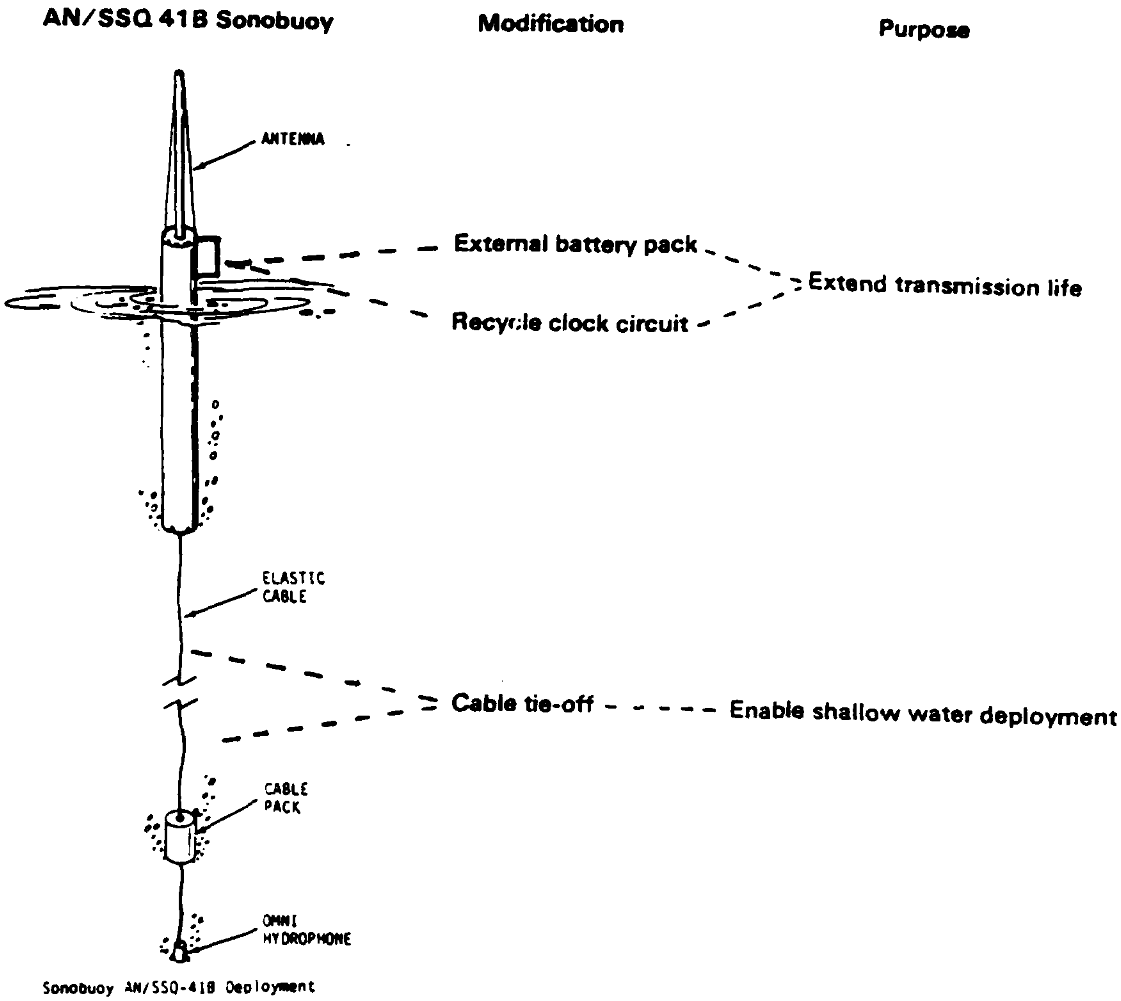


Figure 4. Schematic representation of modifications to AN/SSQ 41B sonobuoys for long-term deployment.

Equipment, Data Collection and Analyses

Standard AN/SSQ 41B sonobuoys, each containing a single omnidirectional hydrophone, signal processing electronics, and a VHF transmitter, were selected as the units to be modified because of their reliability and availability. Three basic modifications were made to the standard sonobuoys prior to the field season (Figure 4). The saltwater-activated battery was replaced with wire fittings to couple to an external power source of six batteries, which served to greatly reduce the number of times the units had to be replaced over the course of the study. The sonobuoy's internal scuttling mechanism was disabled and modified by inserting a recycle clock circuit extending the unit's transmission time past its maximum limit of 8 hours to approximately 72 hours. Lastly, the hydrophone cable was tied off

with a lanyard to limit the depth of the hydrophone to approximately 7 m (22 ft). All modified 41B units underwent laboratory, tank, and freezer tests to assess their reliability prior to shipping them to the field.

The sonobuoy units were moored offshore Barter Island with three Danforth anchors and enough 1.3 cm (1/2 in) anchor line to accommodate a 4:1 scope. Sounds received at the hydrophone were amplified and transmitted to a receiving antenna (Motorola: TAD6043A) externally mounted on a building at the shore station, and connected to a Defense Electronics VHF broadband receiver. The output from the receiver was recorded on an RCA VLP 950 HF video recorder using 6-hour VHS tape speed. The overall response of this recording system was 20 Hz to 10 kHz ± 2 dB, well within the frequency band of bowhead calls.

Data were recorded continuously when the sonobuoy system was operational. Occasionally, when modified buoys were destroyed by ice or could not be deployed during periods of bad weather, expendable sonobuoys (model AN SSQ 57A) were dropped from either the small boat or one of the survey aircraft. In this way, the monitoring station could remain on line without sacrificing one of the modified units during heavy-sea-ice or high-sea-state storm conditions.

All recordings were monitored for bowhead calls. Some tapes were "recycled" in the field when it was determined that no usable data had been recorded. Tapes containing bowhead calls were carefully monitored using the RCA recorder set at real time. The audio signal was played through a Hewlett Packard Dynamics signal analyzer and a visual image of each call was displayed on a HP35721A set at 50- to 850-Hz bandwidth. Simultaneously, the tape was monitored through headphones after being amplified using a Pioneer SA 608 preamplifier. Notation of bowhead calls included date, tape number and count, and sometimes an aural description of call type. Portions of tape containing many calls recorded over a brief time span were dubbed onto a NAGRA IV SJ tape recorder at 19 cm/s (7.5 ips), then replayed through the HP system and headphones at 9.5 cm/s (3.75 ips). Slowing the tape down in this way made it easier to quantify and classify the calls. Bowhead call rate (CR) was derived as number of calls per hour and related to hours of recording effort by date. Calls produced by belukhas and bearded seals were also noted.

Portions of tape were analyzed for ambient noise during recording conditions of heavy- and light-ice cover and calm and high-sea states. Additionally, noise

from small outboard engines and active geophysical vessels were analyzed and compared to the measured ambient levels for the study area.

Collation of Aerial Survey and Acoustic Monitoring Data

Aerial survey-sighting data were plotted in relation to the acoustic monitoring study area. The date and time of sightings were compared to call rates (CR) recorded at the monitoring station. Subsequently, an index to migratory timing past the acoustic station was derived as a combination of daily WPUE and CR for the acoustic study area. In addition, the daily WPUE within the 10-km and 20-km radial limits of the listening station were compared to CR via regression analysis (Zar, 1984).

RESULTS

Aerial Surveys in the Alaskan Beaufort and Eastern Chukchi Seas

Survey Effort and Sighting Summary

A total of 286.93 hours of surveys was flown aboard the two survey aircraft, with 203.25 hours (71%) of this effort in the Beaufort Sea and 83.68 hours (29%) of effort in the Chukchi Sea (Table 5). Line transect surveys were conducted on most flights (45,197 km; 67%), with time spent on random lines alone accounting for 55% (158.85 h) of the total survey time.

Surveys flown aboard N780 over the eastern Alaskan Beaufort Sea during the latter half of August (Appendix A, N780: Flights 1 to 12) accounted for 46.78 hours (17%) of the seasonal effort (Table 6). Line transect surveys were completed in blocks 4 through 9, with coastal search surveys extending as far east as Herschel Island (approx. 139°W) in Canadian waters (Figure 5). Bowhead sightings were generally confined to nearshore Canadian waters (21 whales), near and offshore areas of block 5 (19 whales), with one bowhead seen in block 6.

In September, 91.50 hours of surveys were conducted aboard N780 (Appendix A, N780: Flights 13 to 37) in the Alaskan Beaufort and Chukchi Seas, and 59.08 hours were flown in 302EH (Appendix A, 302EH: Flights 1 to 16) primarily over the eastern Alaskan Beaufort Sea (Table 6). During the first half of the month, line transect surveys were conducted in blocks 1, 2, and 4 through 8 in the Alaskan Beaufort Sea, and in blocks 14 through 18 and 20 in the Chukchi Sea (Figure 6). As in the latter part of August, bowheads were seen in nearshore Canadian waters (13 whales) and throughout block 5 (25 whales), with 1 whale seen

Table 5. Summary of flight effort conducted on two survey aircraft (A/C) in the Alaskan Beaufort and eastern Chukchi Seas, 1986.

Date	A/C	Flt. No.	Sea	Transect Length (km)	Connect Length (km)	Search Length (km)	Total Length (km)	Time on Transect (hr:min)	Total Time (hr:min)	WPUE (whales/hr)
15 Aug	N780	1	Beaufort	34	0	490	524	0:07	2:07	5.66 (BH)
16 Aug	N780	2	Beaufort	492	80	4	576	2:02	2:25	0.41 (BH)
17 Aug	N780	3	Beaufort	780	81	470	1331	3:20	5:27	0.55 (BH)
18 Aug	N780	4	Beaufort	389	55	279	723	1:35	2:54	0
19 Aug	N780	5	Beaufort	655	54	449	1158	2:33	4:33	0
20 Aug	N780	6	Beaufort	710	185	348	1243	2:53	5:34	4.31 (BH)
24 Aug	N780	7	Beaufort	697	181	236	1114	2:55	4:37	0
25 Aug	N780	8	Beaufort	845	100	175	1120	3:25	4:37	0
26 Aug	N780	9	Beaufort	394	43	322	759	1:34	2:57	0
28 Aug	N780	10	Beaufort	846	227	220	1293	3:26	5:29	0.18 (BH)
29 Aug	N780	11	Beaufort	437	90	214	741	1:44	3:03	0
31 Aug	N780	12	Beaufort	281	76	415	772	1:07	3:04	0
1 Sep	N780	13	Beaufort	48	0	87	135	0:11	0:30	0
2 Sep	N780	14	Beaufort	306	94	106	506	1:11	1:57	0
2 Sep	N780	15	Beaufort	208	65	195	468	0:50	1:53	0
3 Sep	N780	16	Beaufort	576	199	468	1243	2:18	5:21	2.99 (BH)
4 Sep	N780	17	Beaufort	437	100	412	949	1:42	3:30	0
5 Sep	N780	18	Beaufort	443	80	161	684	1:43	2:34	0
6 Sep	N780	19	Beaufort	551	54	660	1265	2:08	4:55	1.02 (BH)
7 Sep	N780	20	Beaufort	0	0	368	368	0:00	1:35	12.03 (GW)
			Chukchi	664	55	357	1076	2:54	4:44	9.94 (GW)
7 Sep	302EH	1	Beaufort	738	177	395	1310	3:18	5:52	0.17 (BH)
9 Sep	N780	21	Chukchi	851	174	410	1435	3:24	5:42	0
9 Sep	302EH	2	Beaufort	745	150	343	1238	3:17	5:28	0
10 Sep	N780	22	Beaufort	754	104	286	1144	2:58	4:24	0
11 Sep	N780	23	Beaufort	653	163	364	1180	2:54	5:12	1.54 (BH)
12 Sep	302EH	3	Beaufort	464	93	192	749	2:03	3:13	0
13 Sep	N780	24	Beaufort	0	0	17	17	0:00	0:05	0
			Chukchi	768	122	549	1439	3:01	5:38	1.24 (GW)
13 Sep	302EH	4	Beaufort	744	137	262	1143	3:19	5:07	0.39 (BH)
14 Sep	N780	25	Chukchi	472	41	291	804	1:57	3:21	0.30 (CT)
14 Sep	302EH	5	Beaufort	335	77	220	632	1:28	2:47	0
15 Sep	N780	26	Chukchi	86	0	110	196	0:21	1:10	23.93 (GW)
15 Sep	302EH	6	Beaufort	292	50	52	394	1:17	1:44	0
16 Sep	N780	27	Beaufort	0	0	200	200	0:00	1:10	0
17 Sep	N780	28	Beaufort	819	132	2	953	3:41	4:15	0
19 Sep	N780	29	Beaufort	219	53	232	504	0:50	1:55	2.08 (GW)
			Chukchi	575	79	46	700	2:22	2:52	1.39 (GW)
19 Sep	302EH	7	Beaufort	278	81	250	609	1:14	2:43	0.37 (BH)
20 Sep	N780	30	Beaufort	0	0	6	6	0:00	0:01	50.00 (GW)
			Chukchi	443	71	134	648	1:55	2:44	1.83 (GW)
20 Sep	302EH	8	Beaufort	502	128	149	779	2:15	3:30	0
20 Sep	302EH	9	Beaufort	0	0	270	270	0:00	1:11	0
21 Sep	302EH	10	Beaufort	0	0	240	240	0:00	1:04	0
22 Sep	N780	31	Beaufort	0	0	39	39	0:00	0:09	0
			Chukchi	0	0	467	467	0:00	1:53	0
22 Sep	302EH	11	Beaufort	708	212	43	963	3:10	4:20	0
23 Sep	302EH	12	Beaufort	251	69	432	752	1:08	3:23	0

BH = bowhead whale, GW = gray whale, CT = unidentified cetacean

Table 5 (contd).

Date	A/C	Flt. No.	Sea	Transect Length (km)	Connect Length (km)	Search Length (km)	Total Length (km)	Time on Transect (hr:min)	Total Time (hr:min)	WPUE (whales/hr)
24 Sep	N780	32	Chukchi	389	49	388	826	1:38	3:29	0.57 (CT)
25 Sep	N780	33	Chukchi	208	11	270	489	0:56	2:04	3.38 (GW)
25 Sep	302EH	13	Beaufort	592	175	308	1075	2:39	4:48	1.88 (BH)
26 Sep	N780	34	Beaufort	673	118	175	966	2:46	4:06	0.24 (BH)
26 Sep	302EH	14	Beaufort	903	172	285	1360	4:01	6:04	0.33 (BH)
28 Sep	N780	35	Chukchi	677	109	506	1292	2:38	5:13	0.19 (BH)
			Beaufort	0	0	16	16	0:00	0:04	14.29 (GW)
28 Sep	302EH	15	Beaufort	435	186	412	1033	1:55	4:32	5.52 (BH)
29 Sep	N780	36	Beaufort	55	14	24	93	0:13	0:23	2.63 (GW)
			Chukchi	633	99	115	847	2:38	3:28	1.44 (GW)
29 Sep	302EH	16	Beaufort	450	100	185	735	1:59	3:14	0
30 Sep	N780	37	Chukchi	61	0	1211	1272	0:15	5:13	0.19 (GW)
1 Oct	N780	38	Beaufort	229	36	36	301	0:57	1:14	0
			Chukchi	495	68	298	861	2:07	3:56	2.80 (GW)
1 Oct	302EH	17	Beaufort	794	143	179	1116	3:32	4:59	2.41 (BH)
2 Oct	N780	39	Beaufort	0	0	42	42	0:00	0:10	0
			Chukchi	600	102	521	1223	2:21	5:02	0.40 (GW)
3 Oct	N780	40	Beaufort	307	55	411	773	1:14	3:23	0.89 (GW)
5 Oct	N780	41	Beaufort	0	0	284	284	0:00	1:11	0
6 Oct	N780	42	Beaufort	0	0	133	133	0:00	0:36	0
			Chukchi	585	105	236	926	2:16	3:43	0
6 Oct	302EH	18	Beaufort	451	105	244	800	2:01	3:33	2.54 (BH)
8 Oct	N780	43	Chukchi	668	96	336	1100	2:42	4:32	0.44 (GW)
8 Oct	302EH	19	Beaufort	398	181	118	697	1:46	3:06	0.65 (BH)
9 Oct	N780	44	Beaufort	153	4	286	443	0:38	1:52	0
9 Oct	302EH	20	Beaufort	526	144	425	1095	2:20	4:51	0
10 Oct	302EH	21	Beaufort	441	61	180	682	1:58	3:02	0
11 Oct	302EH	22	Beaufort	89	35	54	178	0:24	0:47	0
12 Oct	N780	45	Beaufort	519	89	162	770	2:22	3:42	2.93 (BH)
13 Oct	N780	46	Chukchi	473	55	84	612	1:57	2:33	0
14 Oct	302EH	23	Beaufort	786	121	80	987	3:28	4:20	0
15 Oct	N780	47	Chukchi	780	142	278	1200	3:11	4:57	0.20 (BH) 0.20 (GW)
16 Oct	N780	48	Beaufort	591	101	171	863	2:24	3:26	0
17 Oct	N780	49	Beaufort	737	153	160	1050	2:55	4:12	0.24 (BH)
18 Oct	N780	50	Beaufort	0	0	258	258	0:00	1:10	0
19 Oct	N780	51	Beaufort	531	88	48	667	2:08	2:44	0
20 Oct	N780	52	Beaufort	0	0	18	18	0:00	0:04	0
			Chukchi	723	170	184	1077	3:09	4:38	0.43 (BH) 1.30 (GW)
21 Oct	N780	53	Chukchi	348	53	436	837	1:27	3:26	0.58 (CT)
23 Oct	N780	54	Beaufort	622	135	467	1224	2:32	5:02	0
24 Oct	N780	55	Chukchi	484	94	252	830	1:54	3:23	0
Beaufort Sea Total				26913	5606	15234	47753	113:48	203:15	
Chukchi Sea Total				10983	1695	7479	20157	45:03	83:41	
Grand Total				37896	7301	22713	67910	158:51	286:56	

Table 6. Monthly summary of flight effort by the two survey aircraft (N780, 302EH), 1986.

	AUG	SEP		OCT		TOTAL	
	N780	N780	302 EH	N780	302 EH	N780	302 EH
Number of Flights	12	25	16	18	7	55	23
Flight Effort Summary							
Transect Length (km)	6,650	11,569	7,437	8,845	3,485	26,974	10,922
Connect Length (km)	1,172	1,986	1,807	1,546	790	4,704	2,597
Search Length (km)	3,622	8,672	4,038	5,101	1,280	17,395	5,318
Time on Transect (hr:min)	26:41	47:24	33:03	36:14	15:29	110:19	48:32
Flight Time (hr:min)	46:47	91:30	59:05	64:56	24:38	203:13	83:43
Unacceptable Weather (days)	4	5	8	5	6	14	14
Aircraft Maintenance (days)	1	0	1	1	1	2	2

in block 7 and 1 whale in block 1. During the latter half of September, line transect surveys were conducted in blocks 1 through 7, 9 through 15 and 17 (Figure 6). Bowheads were seen in blocks 4 (17 whales), 5 (17 whales), 6 (3 whales), 11 (1 whale), and 14 (1 whale.)

In October, 64.93 hours of surveys were conducted aboard N780 (Appendix A, N780: Flights 38 to 55) primarily in the Chukchi Sea, and 24.63 hours were flown on 302EH (Appendix A, 302EH: Flights 17 to 23) over the Alaskan Beaufort Sea (Table 6). During the first half of October, line transect surveys were flown in blocks 1 through 4, 6, 12 through 14, 17 and 18 (Figure 6). Bowheads were seen in blocks 1 (14 whales), 2 (2 whales), 3 (4 whales), 4 (3 whales), 12 (11 whales) and 14 (1 whale). From 16 to 24 October, surveys were flown aboard N780 in the Alaskan Beaufort and Chukchi Seas. Transect surveys were conducted in blocks 1 through 4, 6, 11 through 13 and 17 (Figure 6). Bowheads were seen only in blocks 1 (1 whale) and 13 (2 whales).

Survey Conditions Summary

Survey conditions during the latter half of August were generally good. Low ceilings and fog prevented flying on four of 17 days (Table 6). Visibility conditions during surveys were generally ≥ 5 km under overcast or partly cloudy skies. Ice cover during this period was relatively heavy in the eastern Alaskan Beaufort

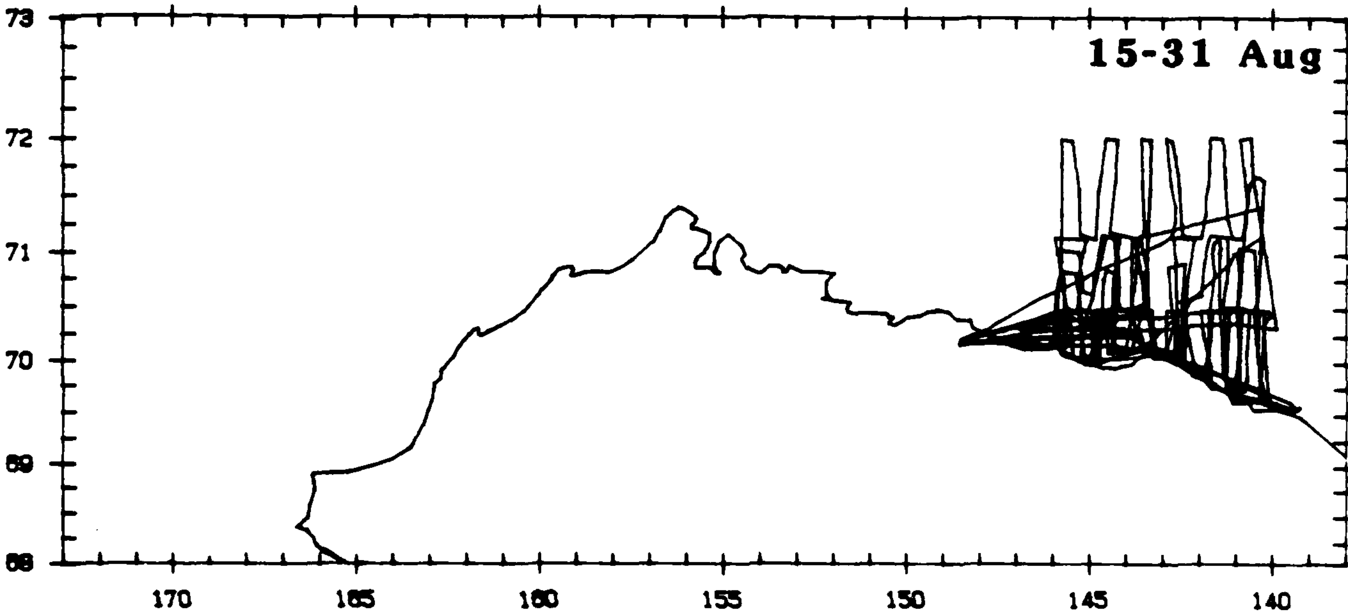


Figure 5. Composite flight track comprising 12 surveys conducted aboard N780, 15-31 August 1986.

Sea (Figure 7). Five to 30 percent cover extended 75 km offshore between Deadhorse and Barter Island, diminishing to less than 5 percent cover east of Barter Island. North of that was a 40-km transition zone where ice cover varied from 30 to 85 percent. Ice cover was heavy (85-99%) north of this zone. A storm on 21 August pushed brash ice up against the barrier islands resulting in a narrow coastal zone ($\leq$3 km) of 50- to 70-percent cover that persisted through the end of the month.

Survey conditions throughout September continued to be generally good. Brief storms and fog prevented flying on 5 of 30 days for N780 and 4 of 20 days for 302EH (Table 6). Visibility during surveys was usually $\geq$10 km under clear, partly cloudy or overcast skies. Ice cover in the Alaskan Beaufort Sea diminished throughout the month of September and there was no ice in the Chukchi Sea (Figure 8). During the first half of the month, cover ranged from 5 to 30 percent between 10 and 120 km offshore followed by a narrow zone of 30- to 70-percent cover and a broad zone of 70- to 95-percent cover. During the latter half of the month, open water extended 50 to 60 km offshore followed by broad zones of 10- to 25- and 25- to 60-percent cover (Figure 8).

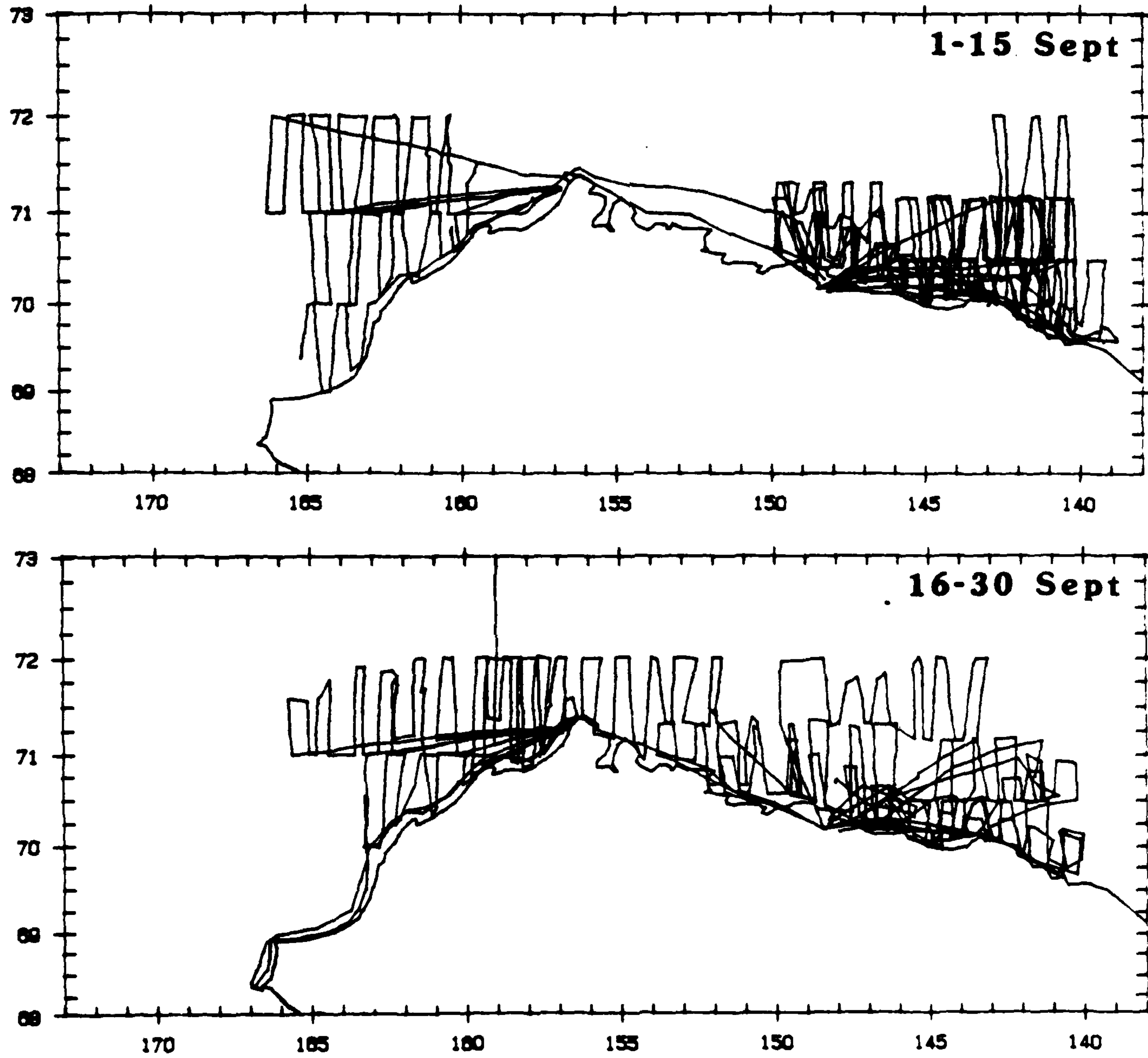


Figure 6. Composite flight tracks of two survey aircraft, N780 and 302EH, comprising: 20 surveys, 1-15 September; 21 surveys, 16-30 September;

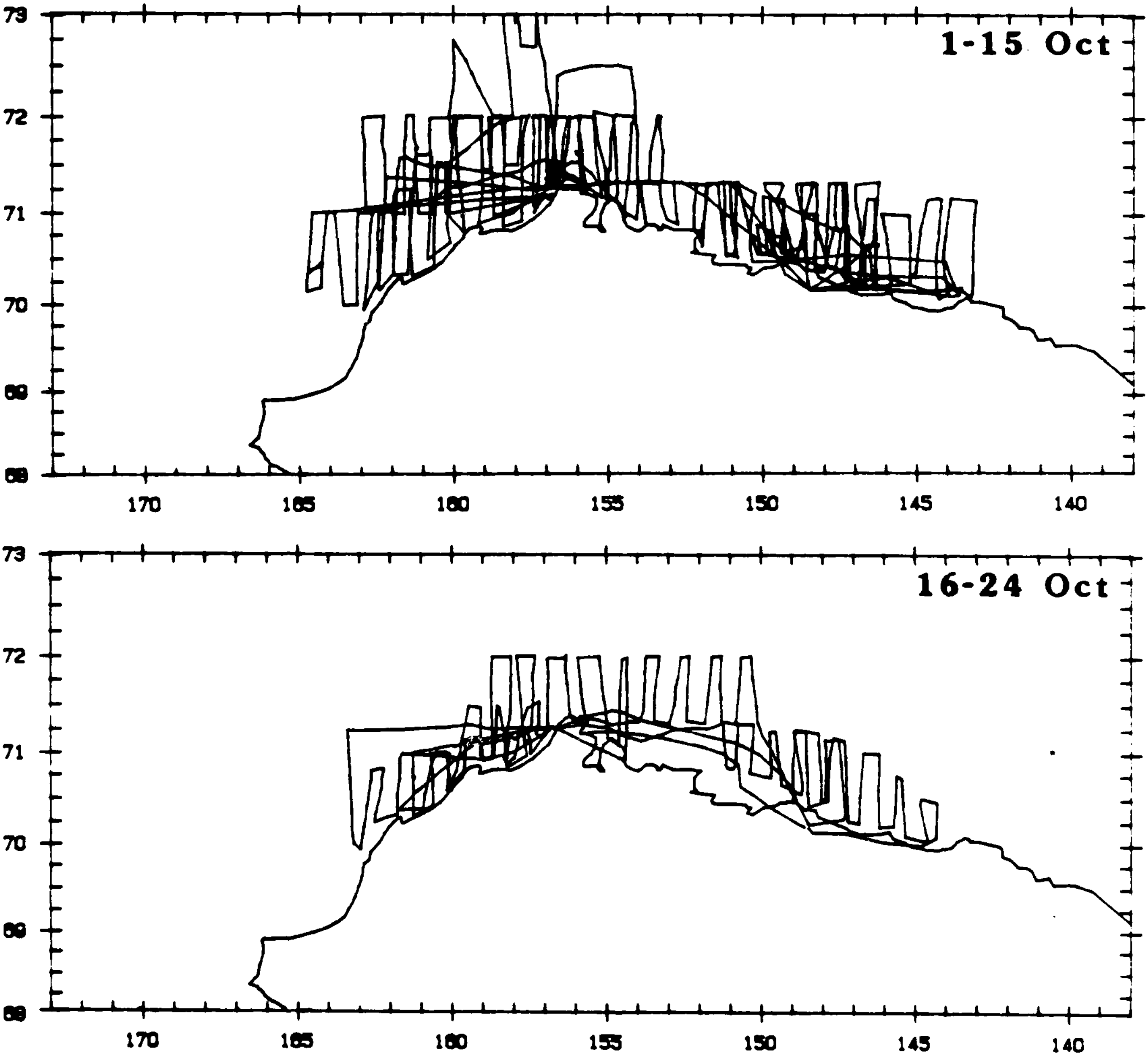


Figure 6 (contd). 17 surveys, 1-15 October; and 8 surveys, 16-24 October 1986.

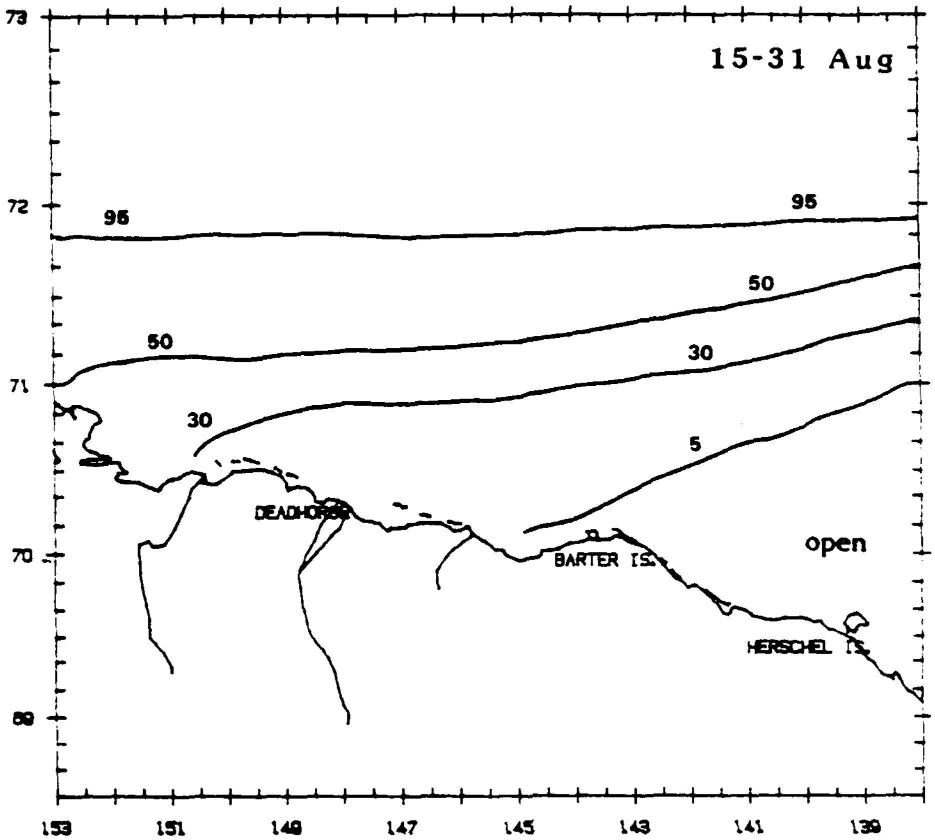
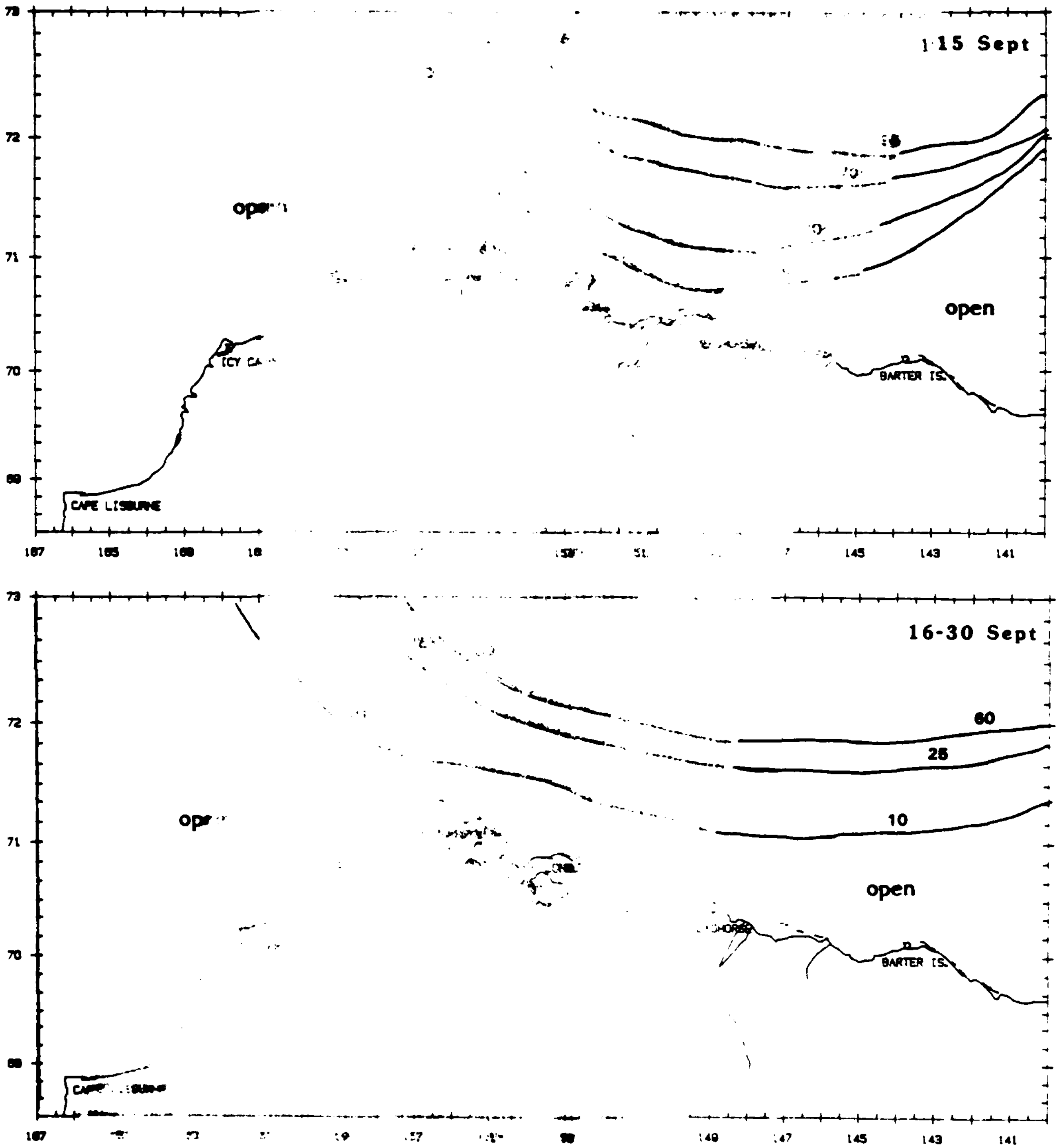


Figure 7. Schematic representation of ice conditions (in percent) in the eastern Alaskan Beaufort Sea, 15-31 August 1986.

In October, storms became more frequent and resultant survey conditions were somewhat worse than those of August and September. Surveys were often flown under overcast skies, in snow squalls or skirting fog, with <1- to 10-km visibility. Storm conditions prevented flying on 5 of 24 days on N780 and 6 of 14 days on 302EH (Table 6). Ice cover remained light through 12 October (Figure 8). Open water extended from 15 to 130 km offshore in the Alaskan Beaufort Sea, and to 150 km offshore in the northeastern Chukchi Sea. East of Deadhorse in the Alaskan Beaufort Sea, ice cover ranged from 10 to 40 percent 15 to 90 km offshore followed by an approximate 40-km zone of 40- to 80-percent cover. Heavy-ice cover (80 to 95%) was at least 110 km offshore in the Alaskan Beaufort Sea, and over 200 km offshore in the northeastern Chukchi Sea. Cold temperatures and strong westerly winds (35-50 kns, 270°T) over 11-12 October caused a dramatic



[illegible] Schematic representation [illegible] (in percent) in the Alaskan Beaufort and northeastern Chukchi Seas: 1-[illegible]ber; 16-30 September;

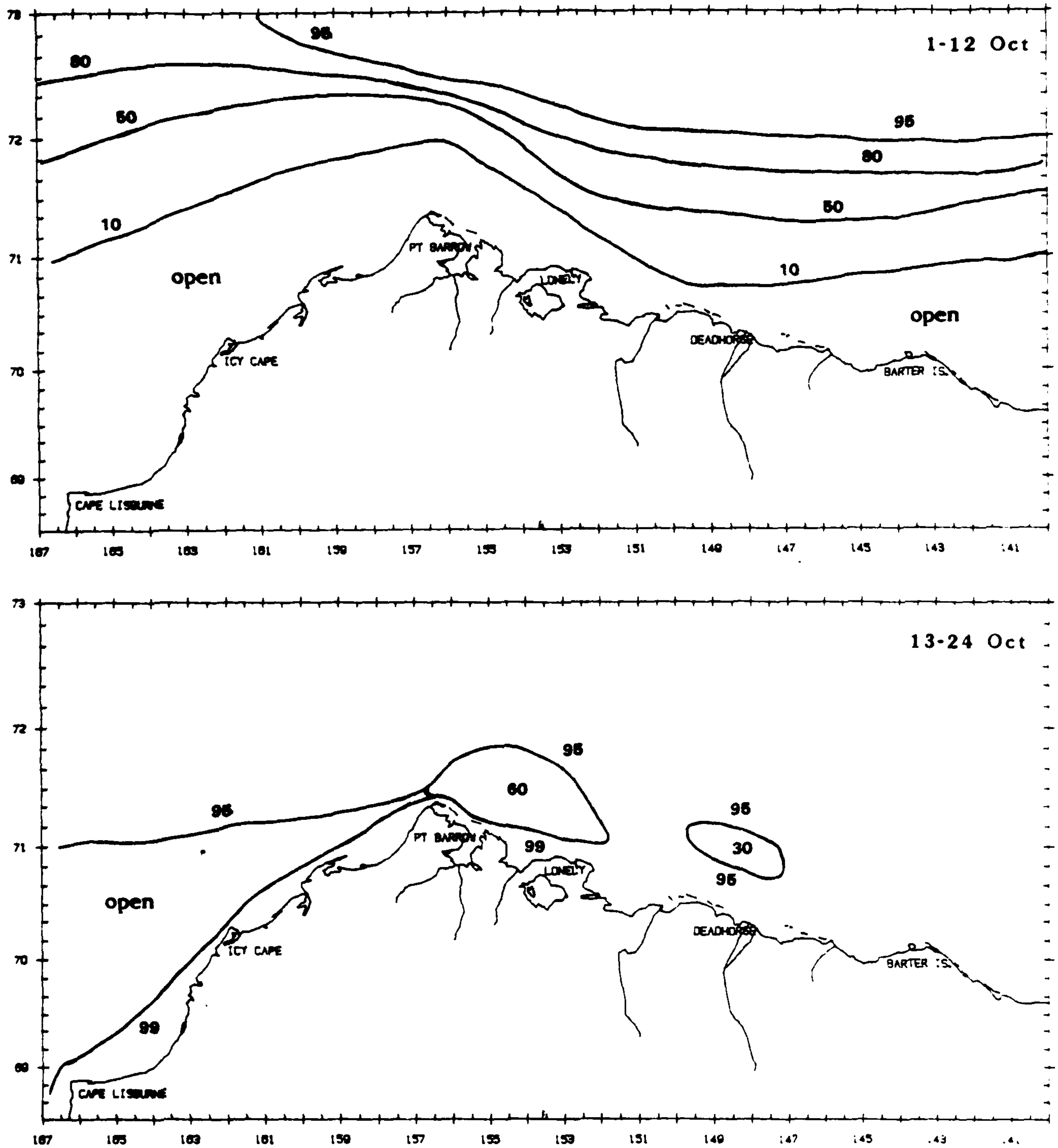


Figure 8 (contd). 1-12 October; and 13-24 October, 1986.

change in ice conditions. After 13 October, ice conditions were heavy over much of the Alaskan Beaufort and northeastern Chukchi Seas (Figure 8). Except for an area of 30-percent cover north and east of Deadhorse and 60-percent cover north and east of Point Barrow, ice cover in the Alaskan Beaufort Sea was ≥95 percent. Shorefast ice (to 2 km) began forming in the Chukchi Sea, with a 30-km band of open water between the shorefast and heavy ice (≥95%) west of Barrow in the northeastern Chukchi Sea.

Ice conditions in 1986 were much lighter than those of the previous 3 years. Ice boundaries averaged over 29 years (1953-81) reported in Webster (1982), and reproduced by La Belle et al. (1983), indicate that ice is usually heavier in the Alaskan Beaufort and northeastern Chukchi Sea than conditions prevalent in 1986. Just as 1980 and 1983 have been considered years of exceptionally heavy-ice cover (Ljungblad et al., 1986a), the 1986 season stands out as a year of notably light-ice cover most similar to 1982 and, to a lesser degree, 1979 survey seasons.

Bowhead Whale (Balaena mysticetus)

a. Distribution

One hundred and seven sightings of 158 bowheads were made by crews aboard the two primary survey aircraft (Table 7, Figure 9). Forty-one bowheads were seen in the latter half of August near the boundaries of the easternmost OCS oil and gas lease areas. Whales were distributed along the coast between Herschel Island and Demarcation Bay (34 whales), approximately 60 km northeast of Barter Island (6 whales), and approximately 55 km northwest of Barter Island (1 whale). This August distribution was similar to, but not comprehensive of, past years (see Figure 28).

Seventy-nine bowheads were seen in September (Table 7, Figure 9). During the first half of the month, whales were seen primarily north and east of Barter Island between 138°47'W and 142°57'W (39 whales), with 1 whale seen northeast of Deadhorse at 70°22'N, 146°51'W. By the latter half of September, bowhead distribution had shifted westward in the Alaskan Beaufort Sea as whales were seen primarily between 140°04'W and 146°02'W (37 whales), with 1 whale seen approximately 40 km north of Cape Halkett at 71°27'N, 151°56'W, and 1 whale seen in the Chukchi Sea at 71°45'N, 162°12'W. Bowhead distribution in September overlapped the boundaries of the eastern OCS oil and gas lease areas and was similar to, but not comprehensive of, that seen in past years (see Figure 28).

Table 7. Summary of marine mammal sightings (number of sightings/number of animals) made by crews aboard the two survey aircraft (A/C), 1986.

DATE	A/C	Flt. No.	Bowhead Whale	Gray Whale	Belukha Whale	Unidentified Cetacean	Walrus	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
15 Aug	N780	1	6/12	0	0	0	0	0	1/1	0	0
16 Aug	N780	2	1/1	0	5/8	0	0	6/8	0	3/9	0
17 Aug	N780	3	3/3	0	0	0	0	0	0	1/2	1/1
18 Aug	N780	4	0	0	4/14	0	0	2/4	0	2/3	0
19 Aug	N780	5	0	0	0	0	0	0	0	0	0
20 Aug	N780	6	10/24	0	7/10	0	0	6/7	0	2/2	0
24 Aug	N780	7	0	0	1/5	0	0	0	0	1/1	1/1
25 Aug	N780	8	0	0	3/22	0	0	1/1	0	2/2	0
26 Aug	N780	9	0	0	6/19	0	0	0	0	1/1	0
28 Aug	N780	10	1/1	0	1/1	0	0	2/2	1/1	0	0
29 Aug	N780	11	0	0	0	0	0	1/2	0	1/1	0
31 Aug	N780	12	0	0	1/2	0	0	4/5	0	1/1	0
1 Sep	N780	13	0	0	0	0	0	0	0	0	0
2 Sep	N780	14	0	0	0	0	0	0	0	9/12	0
2 Sep	N780	15	0	0	1/13	0	0	0	0	5/6	0
3 Sep	N780	16	8/16	0	4/6	0	0	1/1	1/1	10/14	0
4 Sep	N780	17	0	0	2/2	0	0	0	0	0	0
5 Sep	N780	18	0	0	3/3	0	0	0	0	2/2	0
6 Sep	N780	19	1/5	0	0	0	0	0	0	0	0
7 Sep	N780	20	0	18/66	1/1	0	18/56	1/1	0	13/15	0
7 Sep	302 EH	1	1/1	0	8/17	0	0	0	13/26	4/5	0
9 Sep	N780	21	0	0	0	0	0	0	0	6/8	0
9 Sep	302 EH	2	0	0	3/9	0	0	1/2	3/4	6/11	0
10 Sep	N780	22	0	0	1/8	0	0	1/2	0	5/6	0
11 Sep	N780	23	7/8	0	7/25	0	0	0	1/3	5/8	0
12 Sep	302 EH	3	0	0	0	0	0	0	0	0	0
13 Sep	N780	24	0	4/7	(1D)	0	6/8 (1D)	0	0	2/2	0
13 Sep	302 EH	4	2/[illegible]	0	0	0	0	3/3	4/25	13/20	0
14 Sep	N780	25	0	0	0	1/1	1/6 (1D)	0	0	0	0
14 Sep	302 EH	5	0	0	0	0	0	0	0	2/2	0
15 Sep	N780	26	0	5/28	0	0	0	0	0	4/4	0
15 Sep	302 EH	6	4/8	0	0	0	0	0	0	0	0
16 Sep	N780	27	0	0	0	0	0	0	0	0	0
17 Sep	N780	28	0	0	6/68	0	0	0	2/18	14/55	2/3
19 Sep	N780	29	0	4/8 (1D)	0	0	4/9	1/1	8/20	21/54	0
19 Sep	302 EH	7	1/1	0	0	0	0	0	3/24	8/45	0
20 Sep	N780	30	0	3/6 (1D)	0	0	3/7	1/1	0	6/10	0
20 Sep	302 EH	8	0	0	2/3	0	0	0	0	5/21	0
20 Sep	302 EH	9	0	0	0	0	0	0	0	0	0
21 Sep	302 EH	10[1]	0	0	0	0	0	0	0	0	0
22 Sep	N780	31	0	0	0	0	0	0	0	0	0
22 Sep	302 EH	11	0	0	0	0	0	0	0	0	0
23 Sep	302 EH	12	0	0	0	0	0	0	0	0	0
24 Sep	N780	32	0	0	0	1/2	0	0	0	0	0
25 Sep	N780	33	0	2/7	0	0	1/1	0	0	0	0
25 Sep	302 EH	13	8/9	0	1/5	0	0	0	0	0	0

Table 7 (contd).

DATE	A/C	Flt. No.	Bowhead Whale	Gray Whale	Belukha Whale	Unidentified Cetacean	Walrus	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
26 Sep	N780	34	1/1	0	4/13	0	(1D)	0	0	6/7	0
26 Sep	302 EH	14	2/2	0	3/24	0	0	0	0	0	0
28 Sep	N780	35	1/1	1/1	0	0	2/2	0	0	0	0
28 Sep	302 EH	15	21/25	0	2/3	0	0	0	0	1/1	0
29 Sep	N780	36	0	4/6	0	0	0	0	0	0	0
29 Sep	302 EH	16	0	0	0	0	0	0	0	0	0
30 Sep	N780	37	0	1/1	0	0	7/9	0	0	0	0
1 Oct	N780	38	0	4/11	1/10	0	1/1	1/1	0	29/47	0
1 Oct	302 EH	17	8/12	0	0	0	0	0	0	0	0
2 Oct	N780	39	0	2/3	(2D)	0	0	0	0	0	0
3 Oct	N780	40	0	3/3	0	0	0	0	0	0	0
5 Oct	N780	41	0	0	0	0	0	0	0	0	0
6 Oct	N780	42	0	0	1/1	0	1/1	0	0	0	0
6 Oct	302 EH	18	9/9	0	0	0	0	0	0	0	0
8 Oct	N780	43	0	2/2	1/6	0	5/20	0	0	0	0
8 Oct	302 EH	19	1/2	0	5/19	0	0	0	0	1/1	0
9 Oct	N780	44	0	0	2/4	0	0	0	0	0	0
9 Oct	302 EH	20	0	0	0	0	0	0	0	0	0
10 Oct	302 EH	21	0	0	2/34	0	0	0	0	1/2	0
11 Oct	302 EH	22	0	0	0	0	0	0	0	0	0
12 Oct	N780	45	8/11	0	7/98	0	0	0	0	1/4	0
13 Oct	N780	46	0	0	2/2	0	0	0	0	0	0
14 Oct	302 EH	23	0	0	0	0	0	0	0	1/1	0
15 Oct	N780	47	1/1	1/1	2/2	0	(1D)	1/1	0	5/6	1/1
16 Oct	N780	48	0	0	6/14	0	0	0	0	5/10	0
17 Oct	N780	49	1/1	0	0	0	0	0	0	0	0
18 Oct	N780	50	0	0	0	0	0	0	0	0	0
19 Oct	N780	51	0	0	1/2	0	0	0	0	9/41	1/1
20 Oct	N780	52	1/2	3/6	1/14	0	0	0	0	9/16	2/3
21 Oct	N780	53	0	0	1/3	2/2	1/2	0	0	11/12	0
23 Oct	N780	54	0	0	1/2	0	0	0	0	1/1	1/1
24 Oct	N780	55	0	0	0	0	0	0	0	3/14	2/[illegible]
August			21/41	0/0	28/81	0	0	22/29	2/2	14/22	2/2
September			57/79	42/130	48/200	2/3	42/98	9/11	35/121	147/308	2/3
October			29/38	15/26	33/211	2/2	8/24	2/2	0/0	76/155	7/10
TOTAL			107/158	57/156	109/492	4/5	50/122	33/42	37/123	237/485	11/15

1) Radio tracking survey

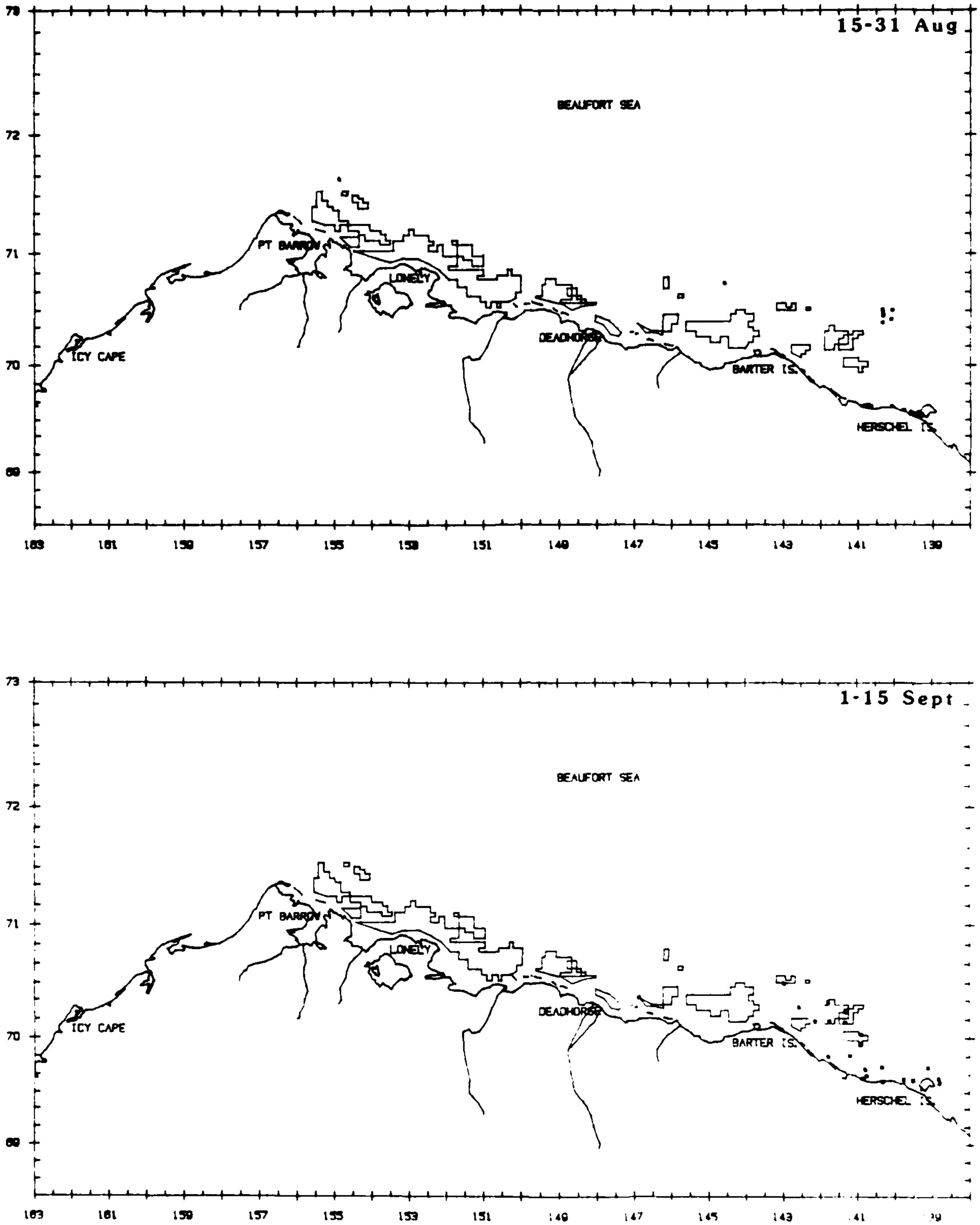
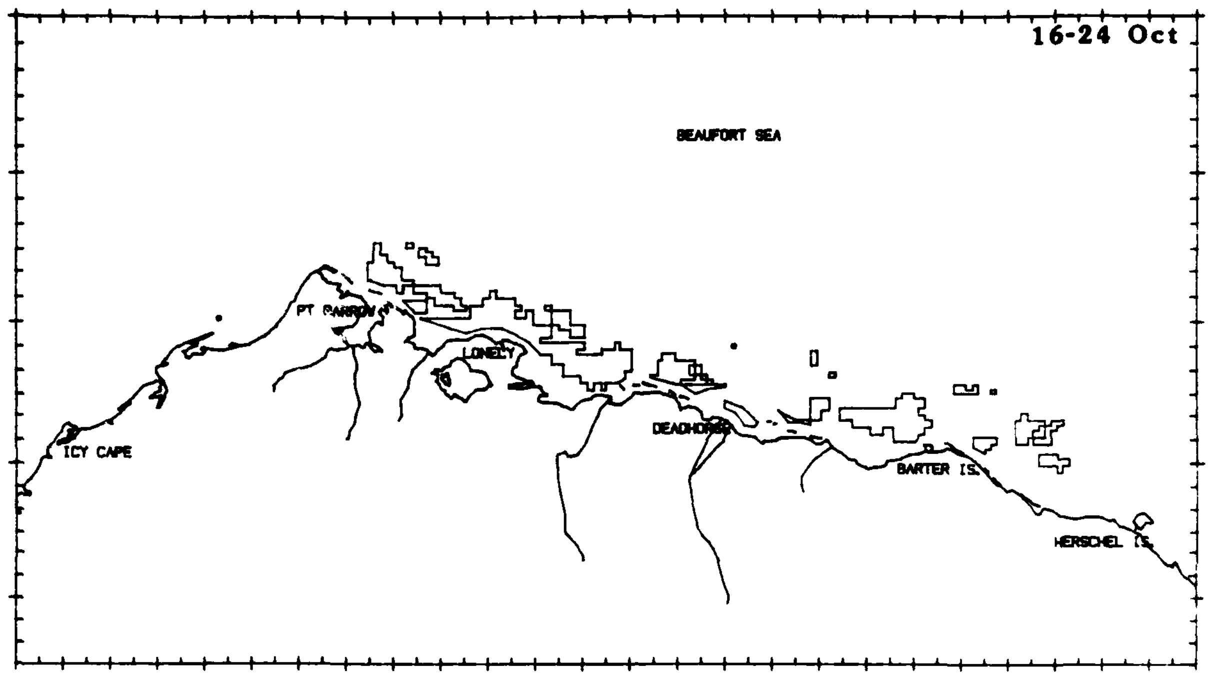


Figure 9. Distribution of 107 sightings of 158 bowhead whales (N780 and 302EH): 21 sightings of 41 bowheads, 15-31 August; 23 sightings of 40 whales, 1-15 September;



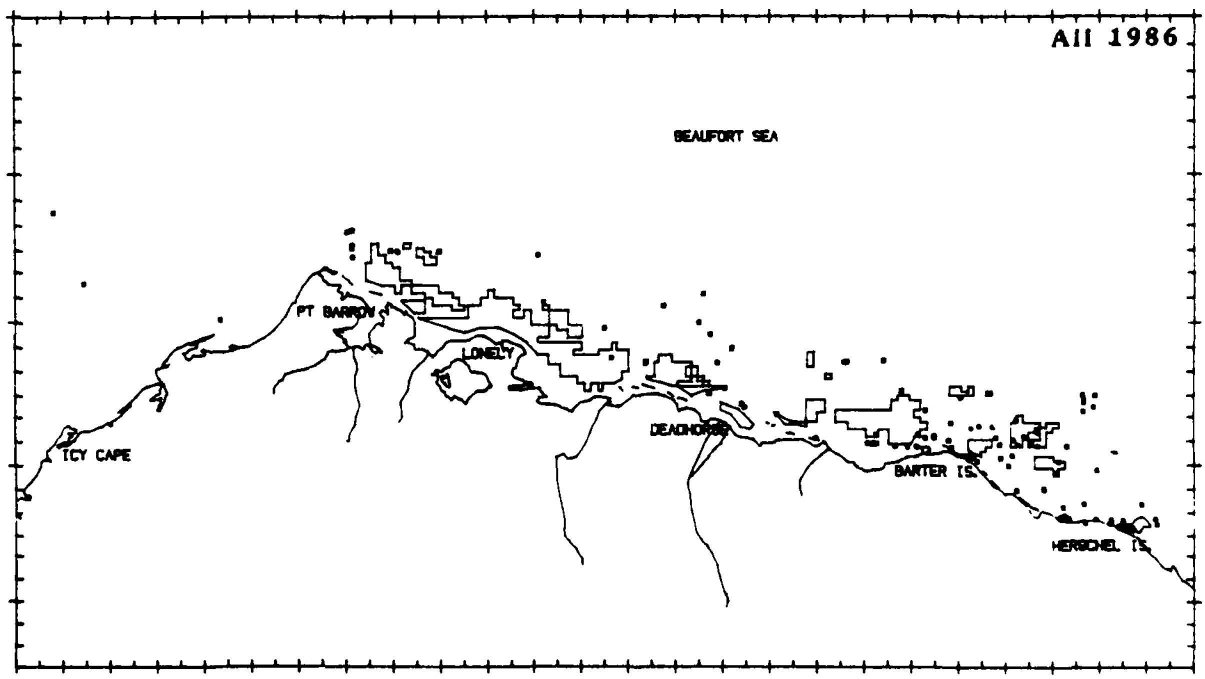
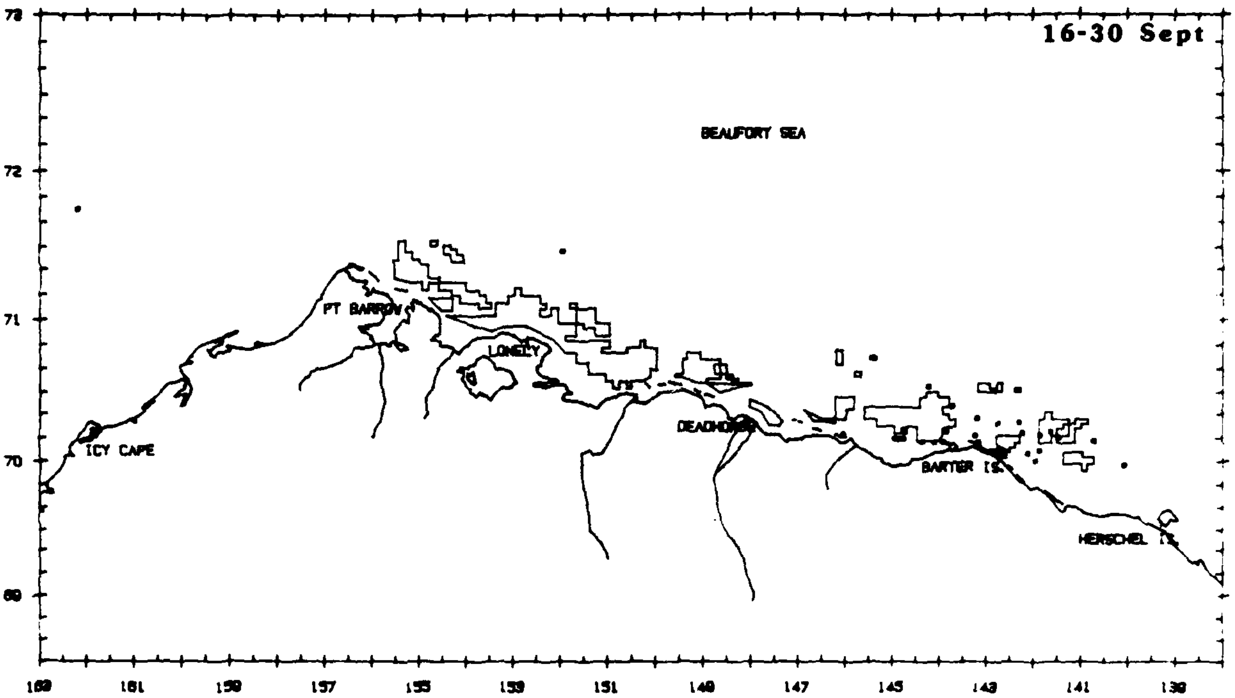


Figure 9 (contd). 34 sightings of 39 whales, 16-30 September; 27 sightings of 35 whales, 1-15 October;



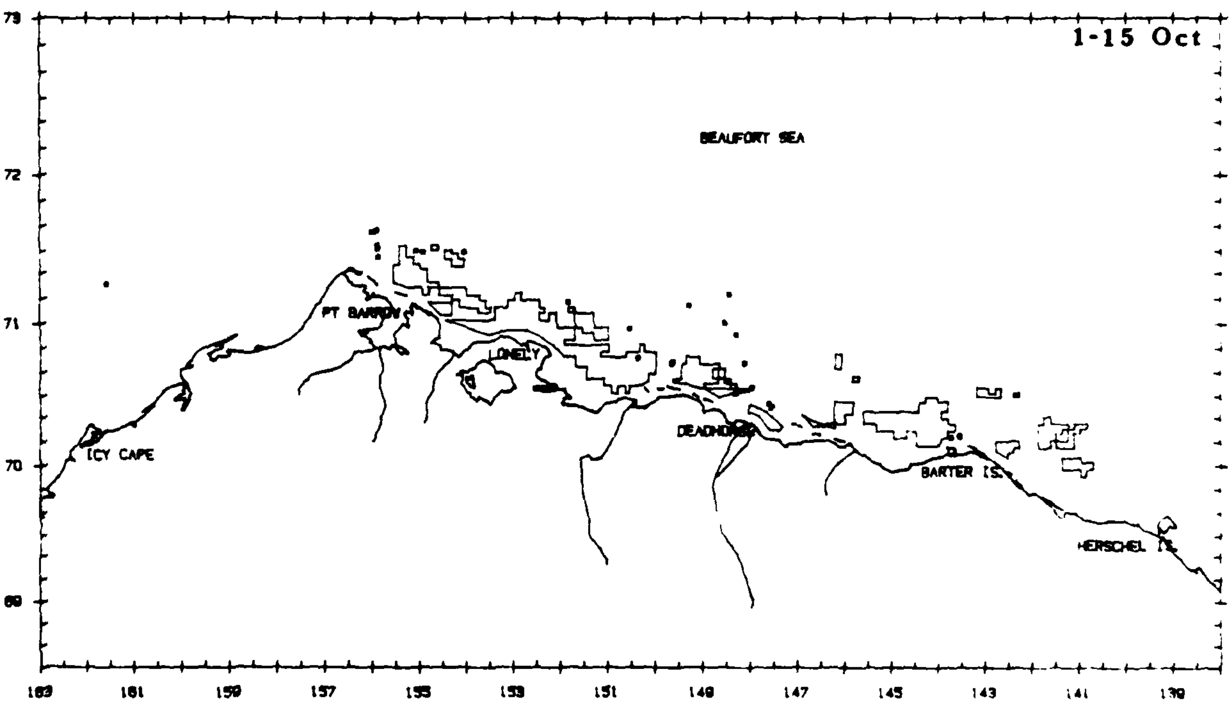


Figure 9 (contd). 2 sightings of 3 whales 16-24 October; and all 1986 sightings. Outlined areas depict OCS oil and gas lease areas within the Beaufort Sea Planning Area of the Alaskan Beaufort Sea.

Thirty-eight bowheads were seen in October (Table 7, Figure 9). During the first half of October, bowheads were seen primarily in the western Alaskan Beaufort Sea between 147°32'W and 155°59'W (31 whales), with 3 whales seen near 70°12'N, 143°35'W, and 1 whale seen in the Chukchi Sea at 71°16'N, 161°34'W. Three bowheads were seen during the latter part of October. One whale was north of Deadhorse at 70°50'N, 147°48'W and 2 whales were seen southwest of Barrow at 71°01'N, 158°41'N. Bowhead distribution in October was similar to past years (see Figure 28), and several sightings were within the northwestern boundaries of OCS oil and gas lease areas.

a.1. Bowhead sighting summary from six aerial survey crews

A total of six aircraft and crews were dedicated to surveying for bowheads in the Alaskan and Canadian Beaufort and Chukchi Seas in August, September, and October (Table 8). Crews aboard the two primary aircraft (N780 and 302EH), whose data are combined throughout this report, flew random line transects from 15 August to 24 October covering the Alaskan Beaufort Sea (north to 72°N, between 140°W to 157°W) and the northwestern Chukchi Sea (68°N to 72°N, 169°W to 157°W) (see Figure 1). One of the primary aircraft (302EH-tagging effort) also flew search surveys in support of the bowhead-tagging effort taking place in the eastern Alaskan Beaufort and western Canadian Beaufort from 30 August to 17 September (Mate, 1987). Crews aboard two additional aircraft conducted systematic transect surveys from 21 August to 3 October from the Alaskan-Yukon border to 35 km east of Cape Bathurst, Canada, to determine ringed-seal distribution and monitor for and photograph bowhead whales (ESL and University of Alberta-ringed seal/whale monitor; P. Norton, personal communication[1]). Also, two research crews conducted studies on bowhead behavior in the eastern and central Alaskan Beaufort Sea (Figure 10). One crew flew systematic transect and behavioral surveys from 3 to 27 September over the eastern Alaskan Beaufort Sea extending north to 71°30'N between 141°W to 144°W(LGL-feeding study; J. Richardson, personal communication[2]) to observe bowhead feeding behavior. The second crew flew fixed grid systematic surveys and behavioral surveys from 2 September to 9 October near drill sites, one of which (Corona study site) extended north to 70°45'N between 143°26'W and 145°28'W and the other (Hammerhead study site), which extended north to 70°45'N between 144°55'W and 146°56'W (LGL-Corona/Hammerhead; S. Johnson, personal communication[3]). Although flight effort and survey rationale varied with each aircraft, an analysis of

Table 8. Semimonthly summary of bowhead sightings (number of sightings/number of whales) made by crews aboard six survey aircraft in the Canadian Beaufort Sea (CBS), the Alaskan Beaufort Sea (ABS) and the Chukchi Sea (CS), 1986.

Aircraft	15-31 August ABS	15-31 August CBS	1-15 September ABS	1-15 September CBS	16-30 September CS	16-30 September ABS	16-30 September CBS	1-15 October CS	1-15 October ABS	1-15 October CBS	16-24 October CS	16-24 October ABS	Total CS	Total ABS	Total CBS	TOTAL
N780/302 EH transect surveys	14/20	7/21	17/27	6/13	1/1	33/38	0	1/1	26/34	0	1/2	1/1	3/4	91/120	13/34	107/158
ESL - ringed seal/ whale monitor	0	17/150	0	16/129	-	0	5/9	-	0	4/20	-	-	-	0	42/308	42/308
LGL - feeding study	-	-	80/326	9/27	-	54/154	8/33	-	-	-	-	-	-	134/480	17/60	151/540
LGL - Corona/ Hammerhead	-	-	9/57	0	-	7/19	-	-	17/76	-	-	-	-	33/152	0	33/152
302 EH tagging support	2/2	38/108	11/39	69/276	-	4/25	7/15	-	-	-	-	-	-	17/66	114/399	131/465
	16/22	62/279	117/449	100/445	1/1	98/236	20/57	1/1	43/110	4/20	1/2	1/1	3/4	275/818	186/801	464/1623

- = no effort reported

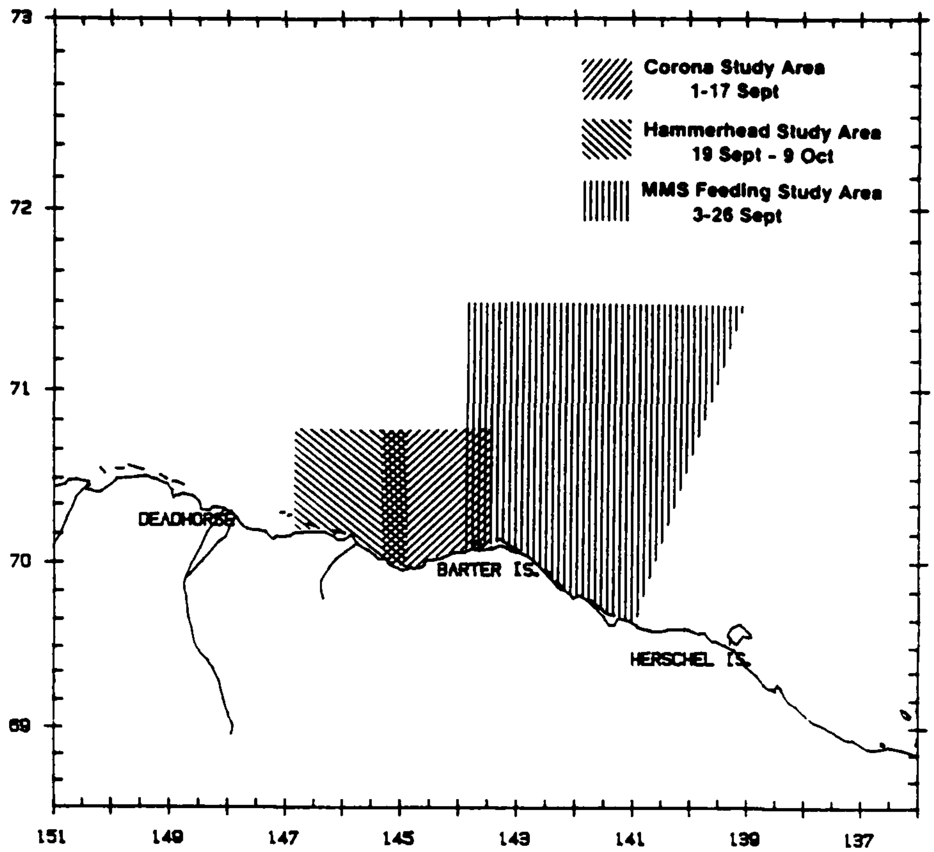


Figure 10. Study areas in the eastern Alaskan Beaufort Sea for two crews conducting systematic surveys to assess bowhead behavior.

all data similar to that done in 1985 (Ljungblad et al., 1986b) was undertaken to present a comprehensive picture of the 1986 fall bowhead migration from August to October.

In the latter half of August, one aircraft (N780) was dedicated to surveying for bowheads in the Alaskan Beaufort Sea (west of 140°W), and three aircraft (ESL-ringed seal/whale monitor, two aircraft; and 302EH-tagging effort) were surveying in the Canadian Beaufort. Bowheads (n = 60) were seen in the eastern Canadian Beaufort (approximately 130°W to 133°W; P. Norton, personal communication[1]) and western Canadian Beaufort (n = 219, from approximately 136°30'W to 140°W; N780; 302EH-tagging effort; ESL-ringed seal/whale monitor), and a few (n = 22) were seen in the Alaskan Beaufort Sea (Figure 11, Table 8). Although most whales were seen between Kay and Shingle Points, Canada, large numbers of bowheads (n > 1000) were not seen in that area as they were in 1985 (Ljungblad et al., 1986b: Table 11). While numerous coastal search surveys were flown between Komakuk Beach (140°10'W) and approx. 136°W by the aircraft and crew flying support for the bowhead-tagging effort (302EH), no offshore transects were completed in the area.

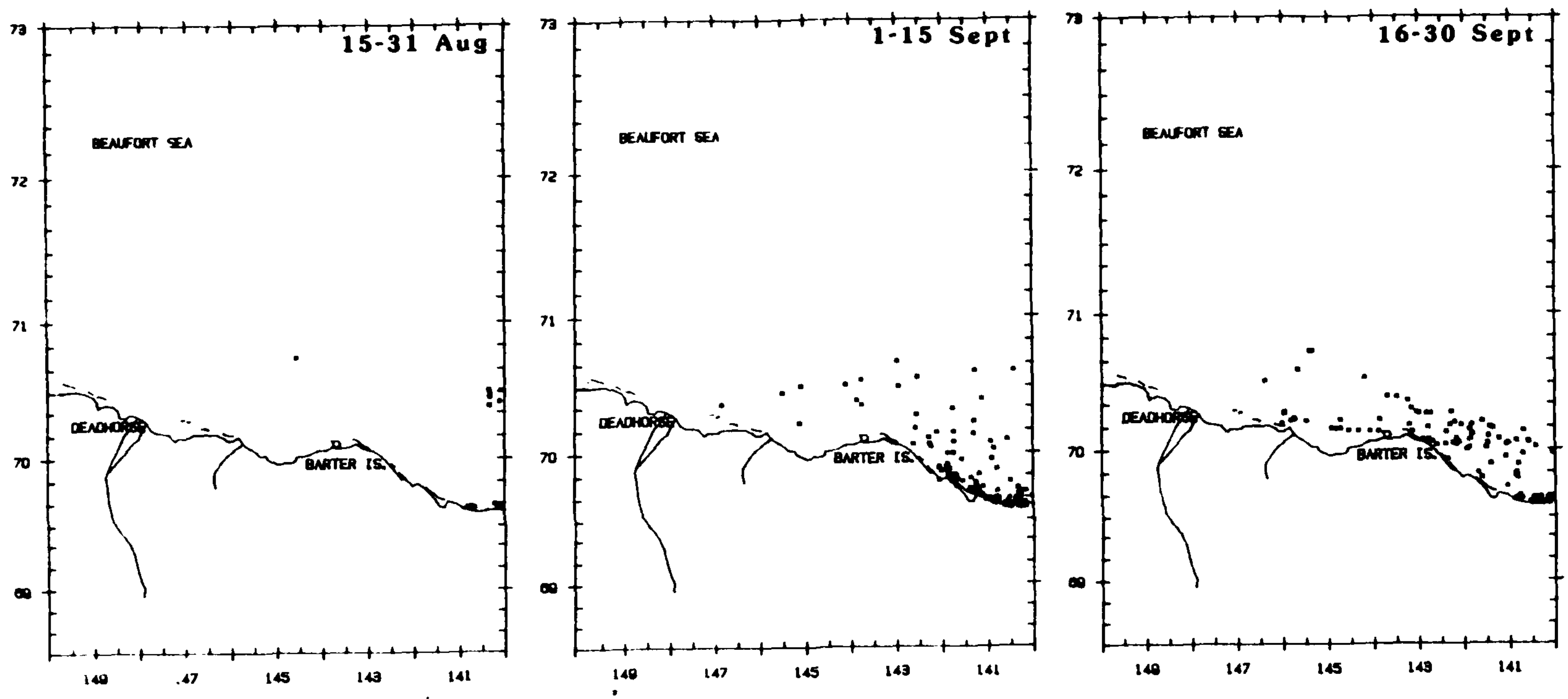


Figure 11. Distribution of 262 sightings of 795 bowheads between 140°W and 150°W from the combined data of five survey aircraft, August-October 1986: 16 sightings of 22 whales, 15-31 August; 116 sightings of 442 whales, 1-15 September;

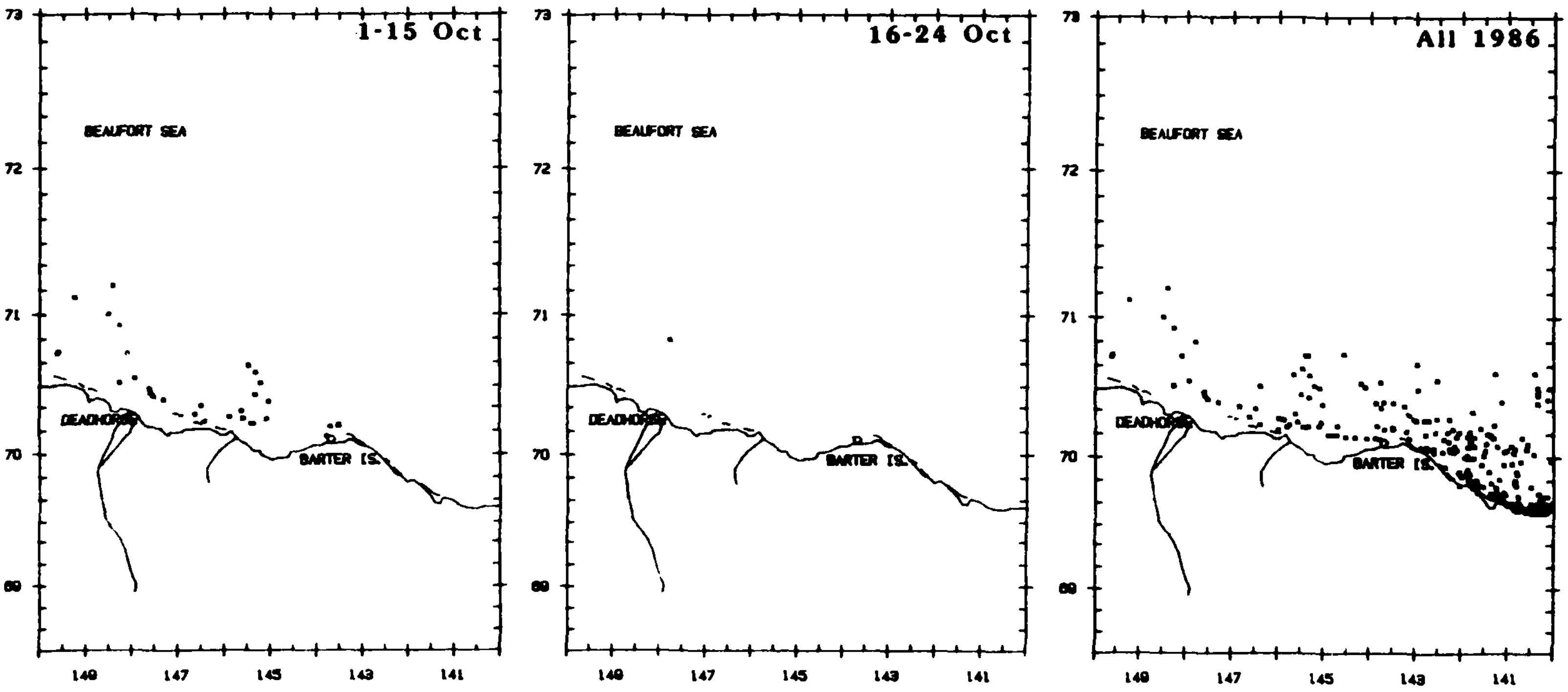


Figure 11 (contd). 97 sightings of 235 whales, 16-30 September; 32 sightings of 95 whales, 1-15 October; 1 sighting of 1 whale, 16-24 October; and all sightings.

The large numbers of bowheads seen in the western Canadian Beaufort in previous years were not seen in 1986 possibly because a dedicated survey effort was not directed to that area as in past years (i.e., August 1985, see Ljungblad et al., 1986b). Bowheads seen in August in the Alaskan Beaufort were approximately 0.5 to 100 km offshore in water 7- to 505-m deep ($\bar{x}$ = 142.4, s.d. = 204.9, n = 16). Although systematic surveys were flown as far west as 146°W (Appendix A, N780: Flights 2, 4, 6-8, 10-12), the most westerly bowhead seen during a survey was at 144°35'W (Appendix A: N780, Flight 2). Three bowheads, including one calf, were reportedly seen on 27 August at 71°45'N, 151°W, by a pilot aboard a helicopter flying in the Harrison Bay region (K. Vaudrey, personal communication[4]).

In the first half of September, four aircraft and research crews (N780/302EH, LGL-feeding study and LGL-Corona/Hammerhead) were dedicated to surveying for bowheads primarily in the Alaskan Beaufort Sea, with three aircraft (302EH-tagging effort and ESL-ringed seal/whale monitor, two aircraft) surveying in the Canadian Beaufort Sea. Bowheads in Canada were seen as far east as 129°40'W and in nearshore areas between Shingle Point and Komakuk (n = 445; Appendix A, N780: Flight 16; P. Norton, personal communication[1], J. Richardson, personal communication[2]; Mate, 1987). Again, large numbers (n >1000) of bowheads were not seen in the nearshore areas of the western Canadian Beaufort Sea as they were in early September 1985 (Ljungblad et al., 1986b: Table 11). In the Alaskan Beaufort Sea, bowheads (n = 449) were seen as far west as 146°51.3'W (Appendix A, 302EH: Flight 4), although the majority were still east of Barter Island (Figure 11). An aggregation of an estimated 25 to 50 feeding and milling whales was seen nearshore (approx. central position 69°35'N, 140°25'W) from 14 September through 26 September. Sightings of whales approaching the Corona drill site, along with consistent sightings of whales west of 141°W (Alaska-Yukon border) resulted in the National Marine Fisheries Service (NMFS) officially recognizing the onset of the migration on 10 September (B. Morris, personal communication[5]). Bowheads in the Alaskan Beaufort Sea were approximately 0.5 to 111 km offshore, in water 7- to 1006-m deep ($\bar{x}$ = 37.1, s.d. = 109.7, n = 117). Systematic surveys were also flown in the northwestern Chukchi Sea (Appendix A, N780: Flights 20-21, 24-26), but no bowheads were sighted.

In the latter half of September, far less survey effort took place in the Canadian Beaufort Sea. Bowheads were still found in the eastern Canadian Beaufort (129°25'W to 131°55'W; P. Norton, personal communication[1]), and a large

group of feeding whales (approx. 35) was seen nearshore between 139°W and 140°30'W (J. Richardson, personal communication[2]). The reduced number (n = 57) of bowheads seen in the Canadian Beaufort may have been the result of less survey effort, when compared to earlier in September, rather than fewer whales in the area. Four crews continued to survey in the Alaskan Beaufort and northeastern Chukchi Seas, resulting in good overall coverage in late September. Bowheads (n = 236) were seen primarily between 140°W and 146°25'W (Figure 11). One bowhead was seen at 71°27.1'N, 151°55.8'W (Appendix A, N780: Flight 34) and one was seen in the Chukchi Sea at 71°45.4'N, 162°11.9'W (Appendix A, N780: Flight 35). The lack of substantial bowhead sightings west of 147°W may be due to two factors. First, large areas of potential bowhead habitat in the Canadian Beaufort were not surveyed in late September and many bowheads may have remained undetected in the area to take advantage of feeding opportunities. Secondly, the pack ice edge (>90% ice cover) was 200-270 km offshore for much of September and, therefore, farther offshore in some areas than the northern limit of the survey blocks (i.e., 72°N). Some bowheads may have travelled along the ice edge and, therefore, migrated to the west north of the survey blocks and undetected on surveys. Bowheads seen in the Alaskan Beaufort in late September were approximately 0.5 to 78 km offshore in water 7- to 90-m deep ($\bar{x}$ = 26.9, s.d. = 17.3, n = 99), which is significantly shallower than depths where whales were seen earlier in the season ($\bar{x}$ = 49.8, s.d. = 128.6, n = 133; t = 1.76, $p < 0.04$). Bowheads seen farther offshore and in deeper water in early fall (August-early September) follow a pattern described previously (Ljungblad et al., 1984a), where early migrating bowheads remain farther offshore in deeper water, while whales migrating in late September and October remain in the shallow nearshore waters for longer periods of time to take advantage of local high prey densities.

In October, only 20 bowheads were seen in Canadian waters between Kay and Shingle Points (P. Norton, personal communication[1]). One hundred ten bowheads were seen in the Alaskan Beaufort (Figure 11) by three survey aircraft (N780/302EH and LGL-Corona/Hammerhead) between 143°30.7'W (Appendix A, 302EH: Flight 18) and 155° 59.0'W (Appendix A, N780: Flight 45). The low number of sightings east of 143°W was likely due to the almost complete lack of survey effort in the area, as only one survey flight was made in the Canadian Beaufort in October (ESL-ringed seal/whale monitor) and no survey flights were flown in the eastern Alaskan Beaufort. Bowheads may have remained in this area to feed, since

Table 9. Summary of OCS drilling site positions, periods of activity, and closest bowhead sighting, 1986.

Site Identifier	Type of Drilling Site	Position (Lat N, Long W)	Period of Drilling Activity	Closest Bowhead Sighting (date and distance)
Corona Prospect	drillship-Canmar Explorer II	70°18.9 144°45.3	2 Sept - 17 Sept	10 Sept 17.6 km SW
Hammerhead Prospect	drillship-Canmar Explorer II	70°22.3 146°00.1	19 Sept - 10 Oct	1 Oct 12.3 km SSE

there were still substantial areas of open water where prey density could have remained high. Three bowheads were seen in the northwestern Chukchi Sea in early October. The far-fewer-than-expected sightings of bowheads in the Chukchi is difficult to explain, but may be due in part to bowheads travelling undetected along the ice edge, which remained substantially north of normally surveyed areas until 12 October. No bowheads were seen on a flight on 23 October (Appendix A, N780: Flight 54) in the Alaskan Beaufort by the only remaining survey aircraft (N780). However, the migration was not officially recognized as over by the NMFS because of the amount of open water that remained in the central Alaskan Beaufort, implying that bowheads could still be migrating through (B. Morris, personal communication[5]). Bowheads seen in October in the Alaskan Beaufort were between 0.5 and 100 km offshore in water 5- to 519-m deep ($\bar{x}$ = 38.6, s.d. = 80.2, n = 44).

a.2. Temporal distribution of bowheads in relation to OCS drilling activities.

Exploratory drilling at two OCS sites was conducted during September and October (Table 9). Activity at and near these sites included actual drilling procedures (drilling, casing, cementing, logging, testing) as well as daily helicopter and vessel (tugboats, supply vessels, and icebreakers) support efforts. The two drill sites were located between 143°W and 149°W. Bowhead sightings collected from all research crews conducting studies in the Alaskan Beaufort Sea were plotted within this 6° window to exhibit the spatial and temporal distribution of whales in relation to these OCS drilling activities (Figure 12). The drillship Canmar Explorer II was utilized throughout the fall and was first positioned at

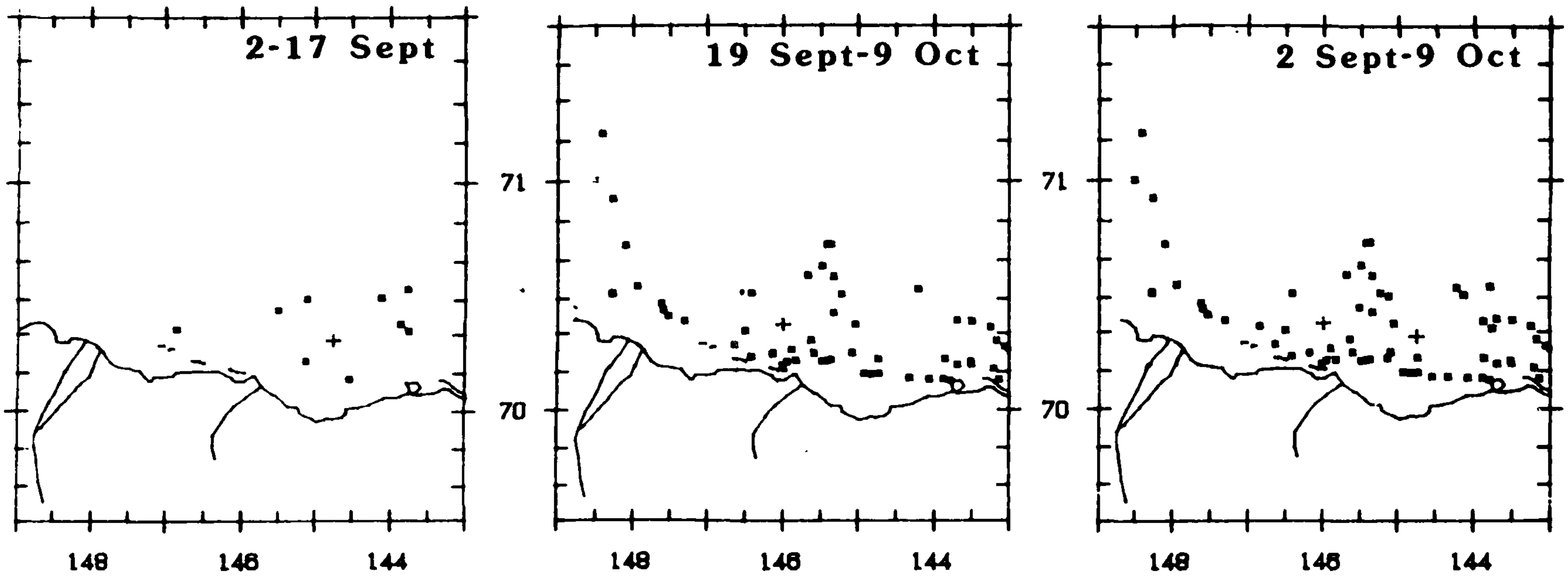


Figure 12. Dis -ibution of 64 sightings of 161 bowheads near two OCS drilling sites: 9 sightings of 28 whales near the Corona drill site, 2-17 September; 55 sightings of 133 whales near the Hammerhead drill site, 19 September to 9 October, 1986; all sightings near both drill sites, 2 September to 9 October 1986.

Corona Prospect (approx. position 70°18.9'N, 144°45.3'W) on 2 September, remaining there until 17 September. Drilling activities at Corona were completed by then, and the drillship was moved to Hammerhead Prospect (approx. position 70°22.3'N, 146°00.1'W) on 18 September where it remained until 10 October. At both sites the Canmar Explorer II was accompanied by an icebreaker, two or three tugboats, and supply vessels. Only one site was operational at any one time since the same drillship was used for each.

In early September, when the drillship was positioned at Corona Prospect, there were 9 sightings of 28 bowheads between 143°W and 149°W made by crews aboard three survey aircraft (Figure 12). Bowheads were sighted as close as 18 km from the drillship (S. Johnson, personal communication[3]; Appendix A, 302EH: Flight 4) and were observed distributed in all directions from the site.

In late September, the Canmar Explorer II moved west to Hammerhead Prospect. Between 19 September and 9 October, 55 sightings of 133 bowheads were made between 143°W and 149°W by crews aboard three survey aircraft (Figure 12). Bowheads were seen as close as 12 km from the drillship (S. Johnson, personal communication[3]; Appendix A, 302EH: Flight 19), and were seen in all directions from the site.

Due to weather restrictions, aircraft maintenance, and prior survey commitments, only four survey flights were completed in the central Alaskan Beaufort (Appendix A: N780, Flight 54; 302EH, Flights 21 to 23) between 10 October when the drillship was moved off of Hammerhead site and 24 October when all surveys were terminated. This represents far less survey coverage than in September and early October, and only one bowhead was sighted in the area (Appendix A: N780, Flight 49).

Throughout September and October, bowheads were seen relatively near the Canmar Explorer II; 75 percent (n = 118) of the bowheads seen between 143°W and 149°W were within 50 km of the ship and 6 whales were within 13 km. Unlike 1985, when all whales were generally distributed north of the drilling sites (Ljungblad et al., 1986b: see Figure 16), bowheads in 1986 were distributed in all directions around the drillship. The observed distribution and the distances maintained between whales and the operating drillship suggests that some avoidance behavior may have been occurring (Figure 12). Two analyses were performed to test for differences in bowhead distribution near the drill sites. First, the average number of bowheads within a 15-km radius around the active drillship ($\bar{x}$ = 3.50,

s.d. = 4.95, n = 2) was compared to the average number of bowheads within a 15-km radius of random points along the drillship isobath (31 m) ($\bar{x}$ = 8.33, s.d. = 12.43, n = 6; Table 10). Only random points east of the drill site were used in this first analysis in order to address the distribution and frequency of bowheads as they approached the drill sites. There was a trend (X^2 = 2.80, df = 1, $p < 0.10$) for more whales to be within 15 km of the random points **east** of the drillship than within 15 km of the drillship, implying that whales may have diverted their migratory route slightly in order to pass around the drilling activities. To test the effect of drill sites on migrating whales approaching and passing the area, the distribution of bowheads near points east and west of the drill site was compared to bowhead distribution near the drill site. There was no significant difference (Table 10) in the frequency of whales seen near operating drillships ($\bar{x}$ = 3/50, s.d. = 4.95, n = 2) and those seen near random points along the 31-m isobath **both** east and west of the operating drillships ($\bar{x}$ = 4.67, s.d. = 9.24, n = 12; X^2 = 0.29, df = 1, $p < 0.50$), suggesting that any diversion in migratory route was temporary and did not persist after the whales had passed the drilling activity.

Few flights were completed in the central Alaskan Beaufort Sea after the drillship was moved permanently out of the area, making it difficult to determine whether bowheads migrated through areas nearer Corona and Hammerhead sites after the potential disturbance was removed. To infer whether the presence of a drillship at a particular location in the Alaskan Beaufort Sea affects the observed frequency of bowheads around that location, the frequency of bowheads within 15 km of active drilling sites (Corona, Hammerhead and Erik in 1985; Corona and Hammerhead in 1986) was tested against the frequency of bowheads within 15 km of the same positions in years when no ship was present (Table 11). Bowhead distribution in heavy-ice years (1980 and 1983) was omitted from the analysis because median depth analysis of the bowhead migratory route indicates that distribution in heavy-ice years may be significantly different than in light-ice years (1979, 1981, 1982, 1984). The observed frequency of bowheads within 15 km of active drill sites ($\bar{x}$ = 1.60, s.d. = 3.05, n = 5) was significantly lower than that observed within 15 km of those sites when no drillship was present ($\bar{x}$ = 13.20, s.d. = 6.76, n = 5; X^2 = 13.2, df = 4, $p < 0.01$), suggesting that the presence of an active drillship and support activities may have some effect on the distribution of bowheads in those areas.

Table 10. Summary of bowhead frequency within 15 km of active drill sites and random points, 1986.

Drillsite			Random Points East of Active Drillsites (17 fm)		
Identifier	Position (Lat N Long W)	# BH within 15 km	Identifier	Position (Lat N Long W)	# BH within 15 km
			A	70°13.8 142°45.0	2
Corona Prospect	70°18.9 144°45.3	0	B	70°17.8 143°25.0	1
			C	70°17.8 144°05.0	9
			A	70°18.1 144°00.0	2
Hammerhead Prospect	70°22.3 146°00.1	7	B	70°17.0 144°40.0	3
			C	70°19.3 145°20.0	33

$x = 3.50$, s.d. $= 4.95$, $n = 2$ $x = 8.33$, s.d. $= 12.42$, $n = 6$

$\chi^2 = 2.80$, df $= 1$, $p < 0.10$

Drillsite			Random Points East and West of Active Drillsites (17 fm)		
Identifier	Position (Lat N Long W)	# BH within 15 km	Identifier	Position (Lat N Long W)	# BH within 15 km
			A	70°13.0 142°45.0	2
			B	70°17.0 143°25.0	1
			C	70°17.8 144°05.0	9
Corona Prospect	70°18.9 144°45.3	0	D	70°19.5 145°25.0	1
			E	70°23.9 146°05.0	0
			F	70°29.0 146°45.0	1
			A	70°18.4 144°00.0	2
			B	70°17.0 144°40.0	3
Hammerhead Prospect	70°22.3 146°00.1	7	C	70°19.3 145°20.0	33
			D	70°29.0 146°40.0	3
			E	70°34.0 147°20.0	0
			F	70°46.7 148°00.0	1

$x = 3.50$, s.d. $= 4.95$, $n = 2$ $x = 4.67$, s.d. $= 9.24$, $n = 12$

$\chi^2 = 0.29$, df $= 1$, $p < 0.50$

Table 11. Summary of bowhead frequency within 15 km of active drill sites (1985, 86) and nonactive drill sites (1979, 81, 82, 84, 86).

BH Within 15 km of Active Drillship Sites				BH Within 15 km of Drillship Sites (when no drillship was present); Light-Ice Years Only		
Year	Identifier	Position	# BH	Year	Identifier	# BH
1985	Erik Prospect (A)	70°20.7 143°58.8	1	1979	(C)	9
					(E)	12
	Corona Prospect (B)	70°18.9 144°49.7	0	1981	(A)	3
					(B)	11
	Hammerhead Prospect (C)	70°21.6 146°21.3	0		(C)	5
					(D)	9
1986	Corona Prospect (D)	70°18.9 144°45.3	0		(E)	10
				1982	(A)	1
	Hammerhead Prospect (E)	70°22.3 146°00.1	7		(B)	2
					(D)	5
				1984	(A)	2
					(E)	1
				1986	(A)*	2
	x = 1.60, s.d. = 3.05, n = 5			x = 14.40, s.d. = 5.41, n = 5		

$X^2 = 11.40$, df = 1, $p < 0.01$

*Erik Prospect was not active in 1986

The effect on bowheads of underwater noise generated by industrial operations may be manifested relatively far from their source because sound travels very efficiently in water (Urick, 1983). The underwater sound fields around offshore drilling sites comprise the noise generated by support vessels, helicopter and fixed wing aircraft overflights, drilling activities and icebreakers (Gales, 1982; Greene, 1985; Moore et al., 1984). Peak noise levels from these industrial sources are generally low frequency (<500 Hz), and comprise a variety of spectral components that are described as either a) broadband "rumbling" sounds that are not concentrated at any particular frequency, or b) narrowband tonal sounds that are concentrated at frequencies associated with rates of machinery operation events (e.g., generators, drills, etc.). Overall, the industrial noise associated with shallow water drilling sites, such as the Corona or Hammerhead sites, is roughly 25 dB above median ambient noise level at 1-km radius, and 10 dB above median ambient level at 10-km radius (Greene, 1985). As a result, bowheads seen closest (12 to 18 km) to the drilling sites could probably detect the underwater noise associated with the ongoing drilling and support activities.

b. Relative Abundance and Density Estimates.

An index of relative abundance (WPUE = no. whales/ hours of survey effort) and a density estimate were calculated for bowheads seen by the two primary aircraft in survey blocks. When calculating abundance, all whale sightings were used regardless of the type of survey being conducted. The calculation of density using strip transect methodologies, however, requires that sightings be made on transect legs (i.e., that sightings be random) and that they occur within a predetermined distance from the aircraft (Hayne, 1949). Therefore, although abundance was calculated for any block in which bowheads were seen, density was calculated only for survey blocks in which whales were seen within 1 km on either side of the aircraft while on transect legs.

Bowhead relative abundance was highest in block 5 in August (WPUE = 1.43) and September (WPUE = 2.36), and in block 1 in October (WPUE = 1.00), reflecting the general westward shift in flight effort and sightings with time (Table 12). Bowhead seasonal relative abundance ranged from 1.96 (block 5) to 0.06 (block 13), with relatively high indices calculated for block 1 (WPUE = 0.44), block 4 (WPUE = 0.57), and block 12 (WPUE = 0.67). Seasonal relative abundance was an order of magnitude greater in Canadian waters (WPUE = 11.41) than for any survey block in Alaskan waters.

Table 12. Monthly and seasonal relative abundance (WPUE = no. whales/hours of survey effort) of bowheads by survey block, 1986.

	AUGUST			SEPTEMBER						
	N780			N780		302 EH		TOTAL		
BLOCK	HRS	BH	WPUE	HRS	BH	HRS	BH	HRS	BH	WPUE
1	3.02	0	0	10.26	0	10.51	2	20.77	2	0.10
2	0	0	-	4.05	0	0.64	0	4.69	0	0
3	0	0	-	2.29	0	4.38	0	6.67	0	0
4	11.90	0	0	5.62	0	11.48	16	17.10	16	0.94
5	13.29	19	1.43	6.61	16	11.22	26	17.83	42	2.36
6	6.83	1	0.15	2.68	0	7.53	3	10.21	3	0.29
7	4.46	0	0	2.56	0	7.31	1	9.87	1	0.10
8	3.31	0	0	2.51	0	0.11	0	2.62	0	0
9	2.58	0	0	0.04	0	2.87	0	2.91	0	0
10	0	0	-	0.12	0	1.89	0	2.01	0	0
11	0	0	-	2.03	1	0.17	0	2.20	1	0.45
12	0	0	-	4.40	0	0	0	4.40	0	0
13	0	0	-	15.57	0	0	0	15.57	0	0
14	0	0	-	9.30	1	0	0	9.30	1	0.11
15	0	0	-	6.45	0	0	0	6.45	0	0
16	0	0	-	0.44	0	0	0	0.44	0	0
17	0	0	-	6.68	0	0	0	6.68	0	0
18	0	0	-	3.08	0	0	0	3.08	0	0
19	0	0	-	0	0	0	0	0	0	-
20	0	0	-	3.55	0	0	0	3.55	0	0
21	0	0	-	0	0	0	0	0	0	-
22	0	0	-	0.80	0	0	0	0.80	0	0
Unblocked	0.04	0	0	1.71	0	0.09	0	1.80	0	0
CANADA	1.35	21	15.56	0.75	13	0.88	0	1.63	13	7.98
TOTAL	46.78	41	0.88	91.50	31	59.08	48	150.58	79	0.52

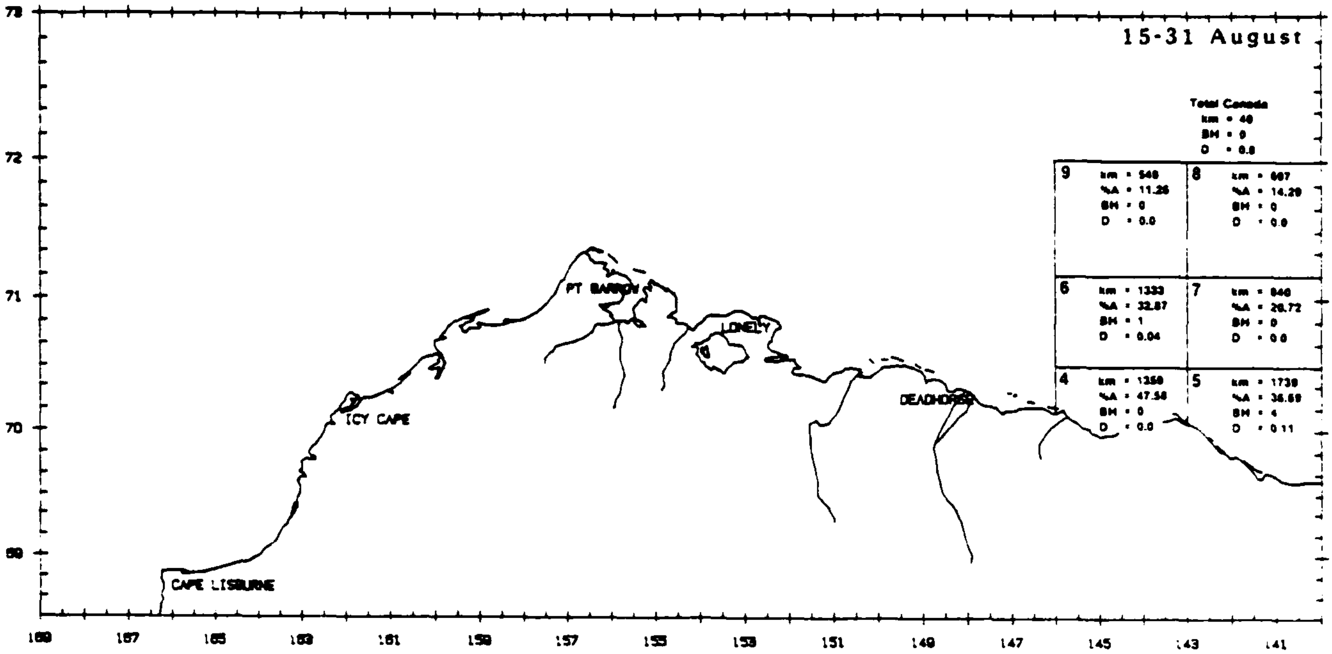
	OCTOBER							SEASONAL						
	N780		302 EH		TOTAL			N780		302 EH		TOTAL		
BLOCK	HRS	BH	HRS	BH	HRS	BH	WPUE	HRS	BH	HRS	BH	HRS	BH	WPUE
1	4.41	1	10.65	14	15.06	15	1.00	17.69	1	21.16	16	38.85	17	0.44
2	1.82	0	3.49	2	5.31	2	0.38	5.87	0	4.13	2	10.00	2	0.20
3	3.92	0	4.67	4	8.59	4	0.47	6.21	0	9.05	4	15.26	4	0.26
4	1.18	0	3.05	3	4.23	3	0.71	18.70	0	14.53	19	33.23	19	0.57
5	0	0	0	0	0	0	-	19.90	35	11.22	26	31.12	61	1.96
6	0.29	0	2.22	0	2.51	0	0	9.80	1	9.75	3	19.55	4	0.20
7	0	0	0	0	0	0	-	7.02	0	7.31	1	14.33	1	0.07
8	0	0	0	0	0	0	-	5.82	0	0.11	0	5.93	0	0
9	0	0	0.14	0	0.14	0	0	2.62	0	3.01	0	5.63	0	0
10	0	0	0.20	0	0.20	0	0	0.12	0	2.09	0	2.21	0	0
11	3.59	0	0.21	0	3.80	0	0	5.62	1	0.38	0	6.00	1	0.17
12	12.09	11	0	0	12.09	11	0.91	16.49	11	0	0	16.49	11	0.67
13	15.71	2	0	0	15.71	2	0.13	31.28	2	0	0	31.28	2	0.06
14	7.80	1	0	0	7.80	1	0.13	17.10	2	0	0	17.10	2	0.12
15	0.39	0	0	0	0.39	0	0	6.84	0	0	0	6.84	0	0
16	0	0	0	0	0	0	-	0.44	0	0	0	0.44	0	0
17	7.35	0	0	0	7.35	0	0	14.03	0	0	0	14.03	0	0
18	2.70	0	0	0	2.70	0	0	5.78	0	0	0	5.78	0	0
19	0	0	0	0	0	0	-	0	0	0	0	0	0	
20	0.05	0	0	0	0.05	0	0	3.60	0	0	0	3.60	0	0
21	0	0	0	0	0	0	-	0	0	0	0	0	0	-
22	0	0	0	0	0	0	-	0.80	0	0	0	0.80	0	-
Unblocked	3.63	0	0	0	3.63	0	0	5.38	0	0.09	0	5.47	0	0
CANADA	0	0	0	0	0	0	-	2.10	34	0.88	0	2.98	34	11.41
TOTAL	64.93	15	24.63	23	89.56	38	0.42	203.21	87	83.71	71	286.92	158	0.55

Bold indicates peak WPUE.

Although the general pattern of bowhead relative abundance was similar to that of past years, the survey block indices were lower than for any year since 1980 (Ljungblad et al., 1986b). In contrast, seasonal abundance in Canadian waters was approximately three times greater than that calculated in prior years. Because group size of feeding whales ($\bar{x} = 5.6$) is significantly larger than that of non-feeding bowheads ($\bar{x} = 2.9$, $p < 0.001$; Ljungblad et al., 1986a), WPUE is strongly influenced by the number of feeding whale groups seen. In 1986, few feeding bowhead groups were seen in the Alaskan Beaufort Sea study area and, except for two feeding whales observed north of Camden Bay on 28 September (Appendix A, 302EH: Flight 15), none were seen after mid-September, contrasting with past years (1979-84) when peak feeding whale WPUE occurred from 15 to 28 September (Ljungblad et al., 1986a). Feeding whales in late August and early September were seen only in nearshore Canadian (n = 22 whales) or block 5 (15 whales) waters, with the farthest west sighting (70°09.6'N, 144°44.1W') that of the two whales seen on 28 September. The open-water conditions that prevailed across the Alaskan Beaufort Sea from early September through mid-October would seem to promote productivity (Schell et al., 1982) and thereby enhance bowhead feeding opportunities. The lack of feeding whale sightings west of Camden Bay, and resultant low WPUE indices in the Alaskan Beaufort Sea, may indicate that feeding opportunities were even better elsewhere.

Bowhead density estimates for the survey blocks generally reflected trends evident in the analysis of relative abundance (Figure 13). Density was highest in block 5 in August (0.11 whales/100 km^2) and September (0.36 whales/100 km^2), and in block 1 (0.15 whales/100 km^2) in October. Seasonal density was highest in block 5 (0.24 whales/100 km^2), followed by block 12 (0.09 whales/100 km^2), blocks 1 and 4 (0.07 whales/100 km^2), block 2 (0.05 whales/100 km^2), and block 6 (0.02 whales/100 km^2). These density estimates are very similar to those calculated for the survey blocks in 1985 (Ljungblad et al., 1986b).

Deriving abundance indices and/or density estimates for specific areas such as the survey blocks is one way to assess how portions of the study area are utilized by the bowhead population. Both derivations indicate that coastal survey blocks 1, 4, 5, and 12 were areas of relatively greater whale concentration. Density estimates were also calculated for bathymetrically derived subregions in the Alaskan Beaufort Sea and are presented with 1979-85 summary data in Appendix B.



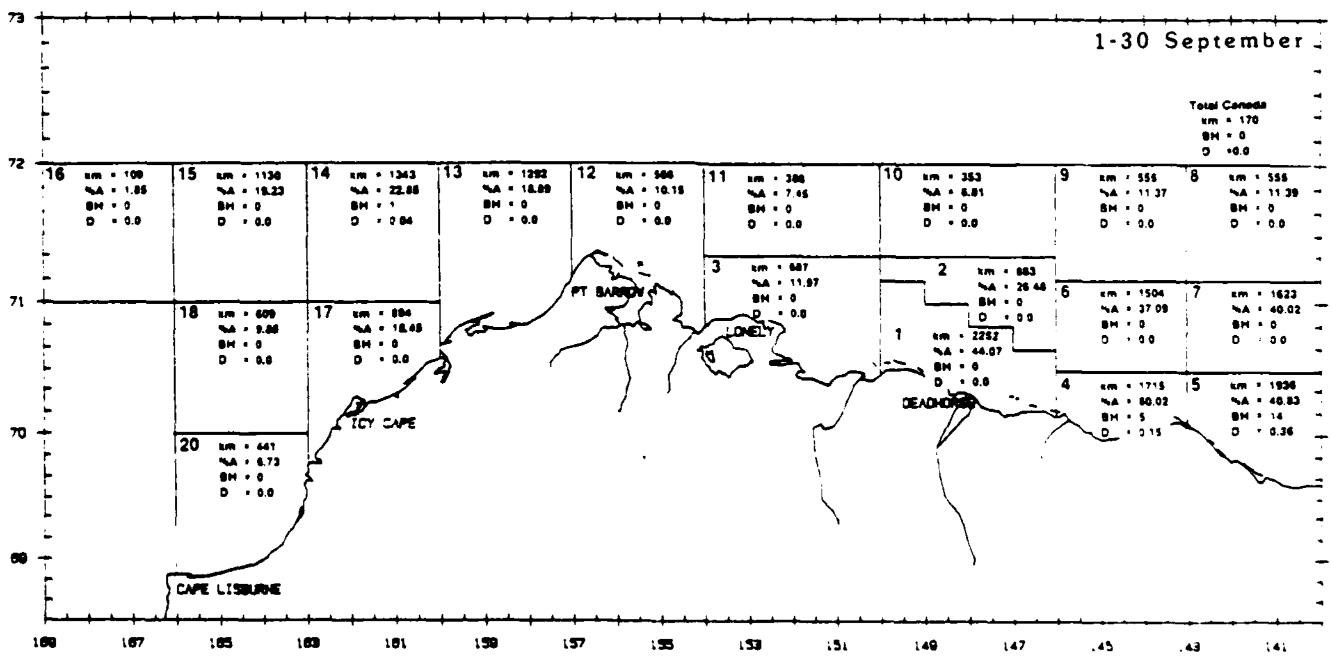
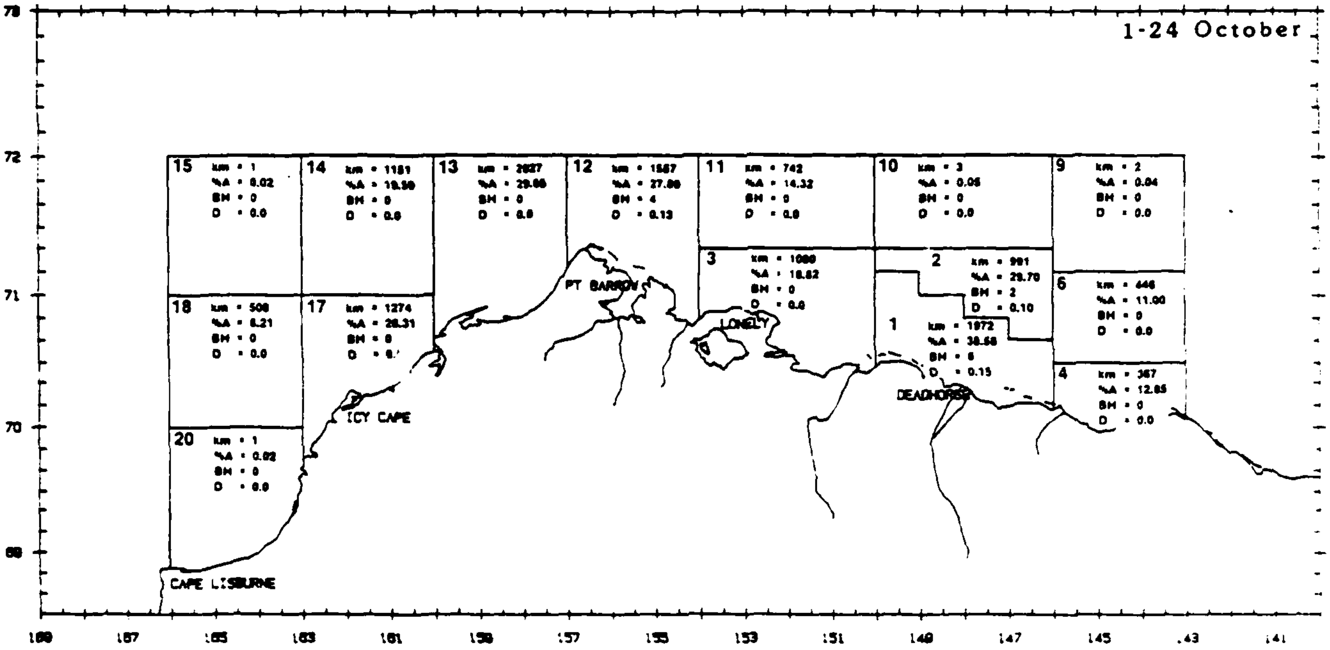


Figure 13. Monthly and seasonal bowhead density estimates (N780 and 302EH): 15-31 August; 1-30 September;



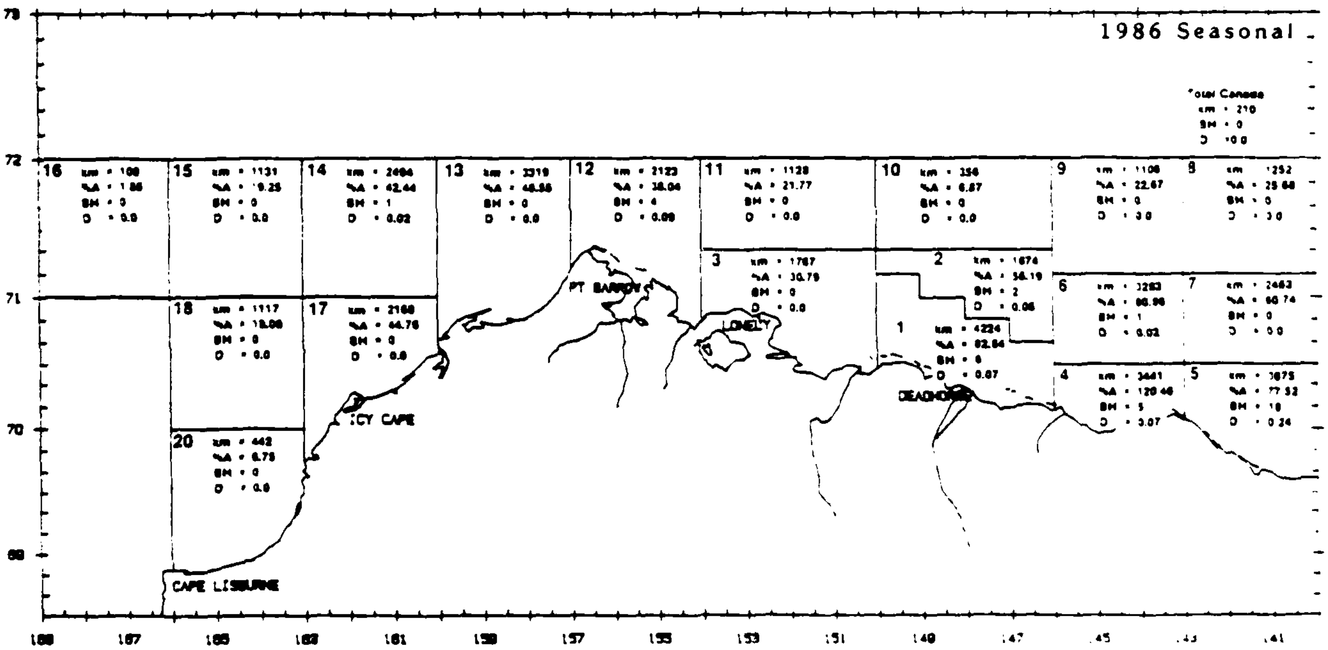


Figure 13 (contd). 1-24 October; 1986 seasonal.

c. **Migratory Timing, Route, and Habitat Relationships**

The timing of the bowhead migration across the Alaskan Beaufort Sea was generally similar to that of past years (Ljungblad et al., 1986b). Although the fall migration did not appear to be underway until early September, there were indications that some whales were moving westward and into the Alaskan Beaufort Sea by late August. One whale was seen north of Camden Bay on 16 August (Appendix A, N780: Flight 2), and three whales were seen swimming west and northwest at medium speeds near the U.S./Canadian demarcation line on 17 August Appendix A, N780: Flight 3). In addition, three whales including one calf were seen north of Harrison Bay (71°45'N, 151°00'W) on 27 August (K. Vaudrey, personal communication[4]). Scattered sightings of bowheads in the Alaskan Beaufort Sea in August are not uncommon, but as in 1986 these whales comprised only a small component of whales seen during this time period and therefore did not represent the movements of the bulk of the bowhead population.

Daily movements of whales near the U.S./Canadian demarcation line sometimes confound efforts to determine a migration start date. For example, a group of 20 bowheads seen feeding just west of Herschel Island on 20 August (Appendix A, N780: Flight 6) seemingly left the area after a 3-day storm, as none were seen there on 24 August (Appendix A, N780: Flight 7). By 25 August, however, "large numbers" of whales were again seen in the area (P. Norton, personal communication[1]). Currently, there is no way to determine if the whales seen on 25 August were new to the area, or were whales returning to the area after moving east, perhaps along the Yukon coast, during the storm. Similarly, some evidence of diurnal movements were noted in bowheads seen along the coast between Kay and Shingle Points during whale-tagging efforts in the Canadian Beaufort Sea. In general, bowheads were seen along the shoreline (≤ 1 km) in the morning as tagging efforts began, but dispersed farther offshore (≥ 5 km) by afternoon. A better understanding of expected variation in bowhead daily movements might help clarify the onset of the migration.

The criterion that we used to define the initiation of the fall migration has been the sighting of one or more adult bowheads swimming in a westerly or northwesterly direction (i.e., 240°-300°T) on two separate surveys within a 5-day period. The initiation of the migration is taken as the date of the first sighting(s). In 1986, one whale was seen swimming at 300°T on 7 September (Appendix A, 302EH: Flight 1), and two bowheads were swimming at 240°T on 11 September

(Appendix A, N780: Flight 23) resulting in a migratory start date of 7 September. This corresponds closely to the migration start date of 10 September established by the NMFS (B. Morris, personal communication[5]). While we determine a migratory "start" date relative to the U.S./Canadian border, the NMFS date is determined relative to industrial sites that are west of the border. The last bowhead seen in the Alaskan Beaufort Sea was on 17 October (Appendix A, N780: Flight 49) although surveys continued through 24 October. Thus, the migratory period in 1986 was defined as 7 September to 17 October.

Bowhead SPUE and WPUE in the Alaskan Beaufort Sea east of 141°W were analyzed by date over the survey season to provide information on the timing of whale movements and the relative abundance of bowheads during the fall migration (Figure 14). Single whales seen on 16 August and 3 September, and a group of five whales feeding nearshore on 6 September (Appendix A, N780: Flight 19) were the only bowhead sightings in the Alaskan Beaufort Sea prior to the start of the migration. After 7 September, daily abundance indices describe a somewhat tri-modal aspect to migratory timing. The first (smallest) phase occurred between 11 September (SPUE = 1.02; WPUE = 1.27) and 15 September (SPUE = 0.65; WPUE = 0.65), the second (largest) phase between 25 September (SPUE = 1.97; WPUE = 2.21) and 1 October (SPUE = 1.29, WPUE = 1.94), and the last phase occurred roughly from 6 October (SPUE = 2.32; WPUE = 2.32) to 12 October (SPUE = 2.26; WPUE = 3.11). The peak migration date was 28 September (SPUE = 4.96; WPUE = 6.01). Although the abundance indices for 1986 were relatively low and similar to those seen in heavy-ice years, the migratory timing they denote was similar to past light-ice years, particularly to that of 1981.

As in past years, the observed bowhead migration route across the Alaskan Beaufort Sea was centered roughly along the continental shelf break. Median water depth at bowhead sightings made on random transects has been employed as one method of defining the axis of the bowhead migration route across the Alaskan Beaufort Sea (Houghton et al., 1984; Ljungblad et al., 1986b). The median depth for September-October bowhead sightings was 25 m, suggesting that the migratory route in 1986 was in shallower water and, therefore, slightly closer to shore than in all years, except 1980.

Most whales (84%, n = 132) were in fact found in shallow (0-50 m) water throughout the season, with all others (16%, n = 26) in 51-to 2000-m water (Table 13). No whales were seen in water over 2000 m deep. Mean depth at

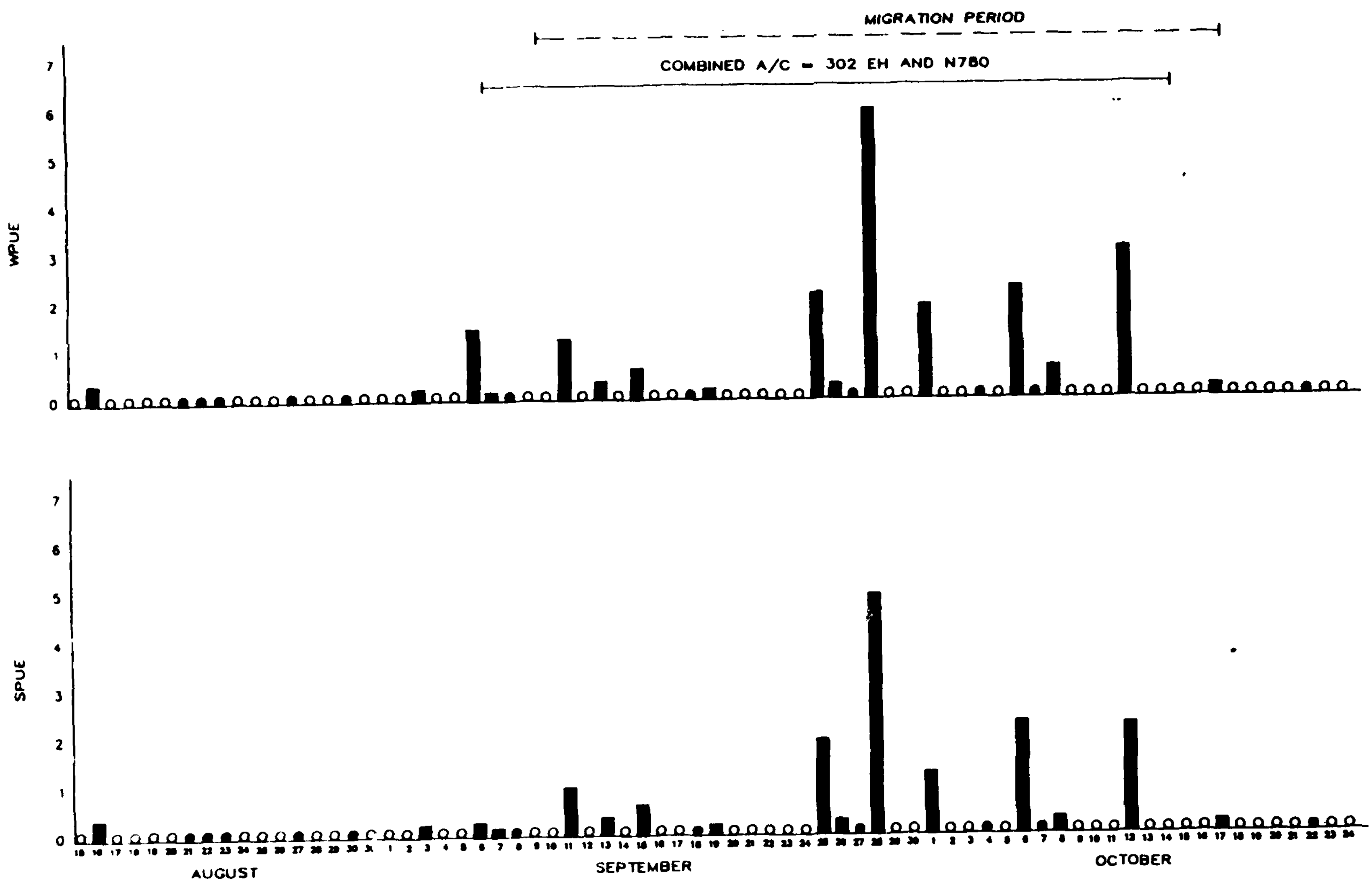


Figure 14. Bowhead sightings per unit effort (SPUE) and whales per unit effort (WPUE) in the Alaskan Beaufort Sea by date, 1986.

Table 13. Semimonthly summary of depths at bowhead sightings, 1986.

	15-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-24 Oct No.(%)	Total No.(%)
Shallow (0-50 m)	34(83)	33(83)	33(85)	29(83)	3(100)	132(84)
Transition (51-2000 m)	7(17)	7(17)	6(15)	6(17)	0	26(16)
Deep (> 2000 m)	0	0	0	0	0	0
TOTAL	41	40	39	35	3	158

bowhead sightings was 50 m, with the whales in the deepest (519 m) water, seen on 8 October (Appendix A, 302EH: Flight 19) north of Prudhoe Bay.

Bowheads were seen in extremely light-ice conditions (0-10% cover) throughout the season (Table 14). As previously mentioned, ice conditions became and remained light from early September through early October. Whales seen during the latter half of August and the first half of October, when there was ice in the Alaskan Beaufort Sea, were always found in open water areas. Only during the latter half of October were whales seen in 41 to 50 percent (n = 2 whales) and 71 to 80 percent (n = 1 whale) ice cover.

d. Behavior and Sound Production.

Fifty-nine percent of all whales seen were either swimming or diving (Table 15). Bowhead swimming direction was not significantly clustered around a mean heading in August, nor during the first half of September (Figure 15). During the latter half of September, swimming direction was significantly clustered around a heading of 294°T ($p < 0.001$) and in October there was significant clustering around a mean heading of 302°T ($p < 0.001$). The combined mean heading of bowheads in the Alaskan Beaufort Sea during the latter half of September and October was 298°T ($p < 0.001$). Swimming direction of bowheads in the Chukchi Sea in late September and October (n = 4) was not clustered around any mean heading.

Most bowheads swam at slow speeds (< 2 km/hr) during the latter half of August (78%, n = 32) and the first half of September, (68%, n = 27; Table 16).

Table 14. Number (No.) and percent (%) of bowheads found in each ice cover class, 1986.

Ice Cover (%)	15-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-24 Oct No.(%)	Total No.(%)
0-10	41(100)	40(100)	39(100)	35(100)	0	155(98)
11-20	0	0	0	0	0	0
21-30	0	0	0	0	0	0
31-40	0	0	0	0	0	0
41-50	0	0	0	0	2(67)	2(1)
51-60	0	0	0	0	0	0
61-70	0	0	0	0	0	0
71-80	0	0	0	0	1(33)	1(1)
81-90	0	0	0	0	0	0
91-100	0	0	0	0	0	0
TOTAL	41	40	39	35	3	158

During the latter half of September, bowheads were swimming at slow (21%, n = 8), medium (18%, n = 7), and fast speeds (18%, n = 7), and by the first half of October most whales (46%, n = 16) were swimming fast (>4 km/hr). The change to significant northwesterly swimming direction and faster swimming speeds from mid-September on further indicates that whales were strongly directed in their migratory movements by that time.

Bowheads that were not swimming or diving were resting (4%, n = 7), feeding (26%, n = 40), milling (1%, n = 2), part of a cow-calf association (5%, n = 8), or displaying (6%, n = 9). Feeding bowheads were seen on two occasions in August and three times in September. The first group of 8 feeding whales was among 12 bowheads seen on 15 August (Appendix A, N780: Flight 1) near Clarence Lagoon (approx. 69°38'N, 140°47'W). Feeding whales could be seen subsurface as they repeatedly turned and swam in concentric circles in shallow milky-green water. Photographs of whales within concentric swirls indicate that the feeding whales were abruptly turning back repeatedly over a very localized area, suggesting that their prey was distributed in discrete patches. One feeding whale blew four times underwater, a behavior common to whales feeding in Canadian waters (Würsig et al., 1985). A cow-calf pair was seen very close to shore ($\leq$ 200 m) among the feeding whales. The cow appeared to alternate short bouts of feeding with brief

Table 15. Semimonthly summary of bowhead behavior, 1986.

	15-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-24 Oct No.(%)	Total No.(%)
MIGRATORY						
Swim	6(14)	24(60)	28(72)	25(71)	3(100)	86(54)
Dive	2 (5)	3 (8)	1 (2)	0	0	6 (4)
SOCIAL						
Rest	3 (7)	0	3 (8)	1 (3)	0	7 (4)
Feed	28(68)	10(25)	2 (5)	0	0	40(26)
Mill	1 (3)	1 (2)	0	0	0	2 (1)
Cow-Calf	0	0	2 (5)	6(17)	0	8 (5)
Display	1 (3)	2 (5)	3 (8)	3 (9)	0	9 (6)
TOTAL	41	40	39	35	3	158

periods of swimming alongside the calf. In addition to the feeding whales, two whales were seen resting just outside the area of milky-green water. Bowheads were also seen feeding nearshore on 20 August just west of Herschel Island (Appendix A, N780: Flight 6). As on 15 August, feeding whales left swirls and contrails in light milky-green water. Whales turning back on localized areas often blew only once before submerging again. Underwater blows were seen from four of the whales that appeared to be feeding. Two of three bowheads seen offshore on 20 August were swimming in a direction (185°T) that would take them toward the feeding aggregation. Bowheads were again seen feeding near Herschel Island on 3 September (Appendix A, N780: Flight 16), along the coast west of Demarcation Bay on 6 September (Appendix A, N780: Flight 19), and north of Camden Bay on 28 September (Appendix A, 302EH: Flight 15). Three of the five whales seen feeding on 3 September were part of a loose aggregation of 13 bowheads in coastal waters off Herschel Island. Other whales in this aggregation were breaching (1 whale), rolling (1 whale), milling (4 whales), or swimming slowly in various directions. The other two feeding whales seen on 3 September were nearshore just east of Demarcation Bay. These whales abruptly turned back over a localized area as seen in coastal feeding whales on 15 and 20 August. One

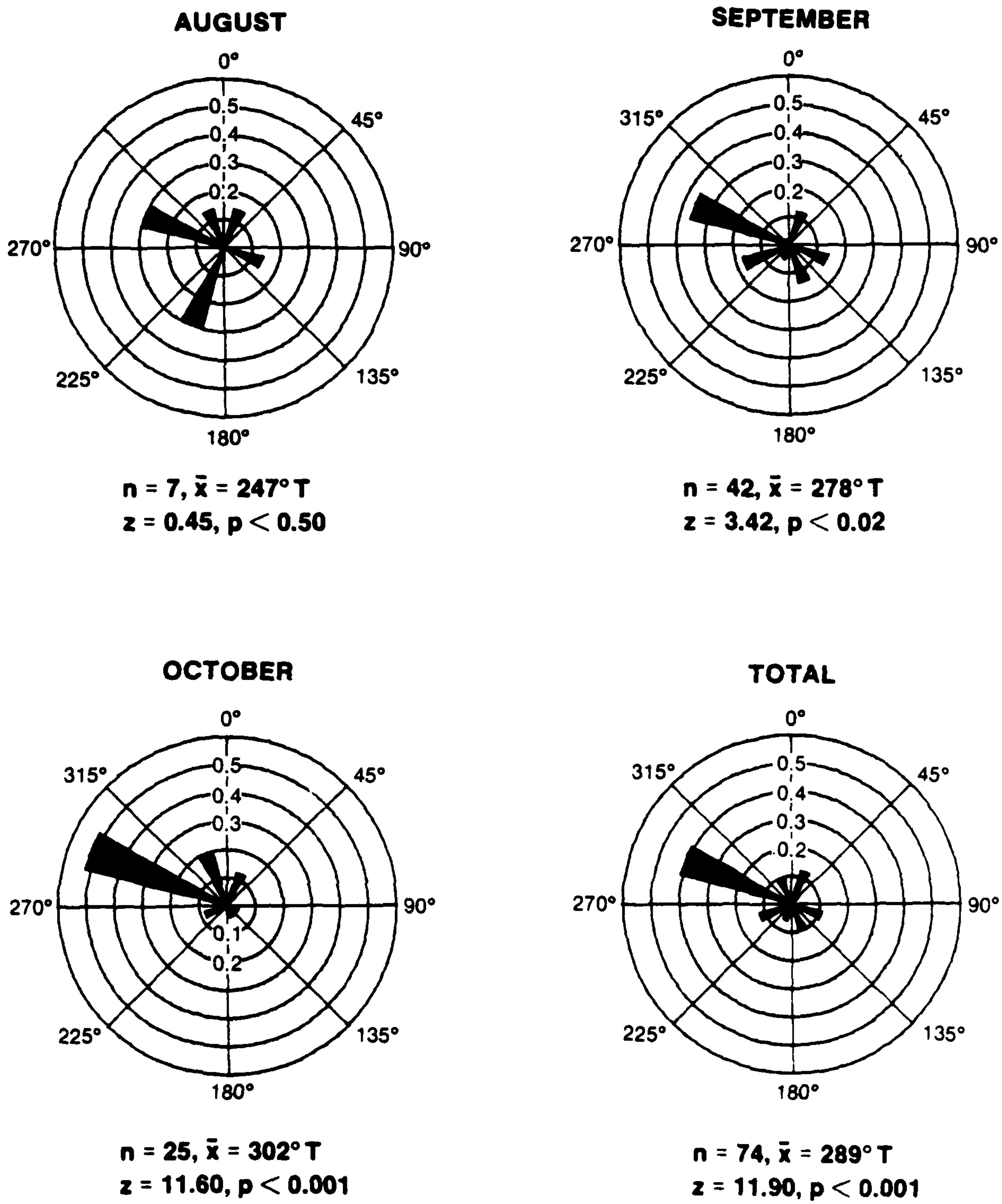


Figure 15. Bowhead swimming direction in the Alaskan Beaufort Sea, 1986.

Table 16. Semimonthly summary of bowhead swimming speeds, 1986.

	15-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-24 Oct No.(%)	Total No.(%)
Still 0 km/hr	4(10)	0	3 (7)	1 (3)	1	8 (5)
Slow < 2 km/hr	32(78)	27(68)	8(21)	4(11)	2(67)	73(46)
Medium 2-4 km/hr	3 (7)	0	7(18)	6(17)	1(33)	17(11)
Fast > 4 km/hr	0	0	7(18)	16(46)	0	23(15)
Unknown	2 (5)	13(32)	14(36)	8(23)	0	37(23)
TOTAL	41	40	39	35	3	158

underwater blow was seen near these two feeding whales, but a third bowhead was not seen. There were no prolonged observations made on the feeding whales seen on 6 September (5 whales) and 28 September (2 whales).

The incidence of feeding bowheads in 1986 was unusual, compared to past years when ice conditions were light in that it was confined to the eastern Alaskan Beaufort Sea. Generally in years of light ice, bowhead feeding groups have been observed in localized areas across the Alaskan Beaufort Sea, and only in years of heavy ice has feeding been largely confined to areas east of Barter Island (Ljungblad et al., 1986b). Also, the relative abundance (WPUE) of feeding whales in the Alaskan Beaufort Sea has been highest during the latter half of September (Ljungblad et al., 1986a), a time period during which only two feeding bowheads were seen in 1986. The reason for the low numbers of feeding whales in the Alaskan Beaufort Sea in 1986 are unclear. The lack of ice cover during much of September and early October would seem to foster light-dependent primary productivity (Schell et al., 1982) and, therefore, promote relatively dense populations of copepods and euphausids upon which bowheads feed (Lowry and Frost, 1984). It is possible, however, that prey availability was higher in Canadian waters, or along the ice edge far offshore. The eastern Canadian Beaufort Sea is generally recognized as the primary bowhead feeding ground (Fraker and Bockstoce, 1980; Frost and Lowry, 1984) and observations of whales feeding there

were made by Würsig et al. (1985) during the summers of 1980-84. Bowheads exhibited various feeding strategies in different locations each year, with no discernible consistent utilization pattern (Würsig et al., 1985). Bowheads likely rely on finding localized areas of especially abundant prey (Frost and Lowry, 1984) and whales may simply remain in dense prey areas until the food source is exhausted. Conversely, bowheads may have encountered more localized feeding opportunities along the offshore ice edge than nearshore in the Alaskan Beaufort Sea. Upwelling, which brings nutrient-rich waters toward the surface, usually occurs along ice edges and may have led to localized blooms of bowhead prey. Because the ice edge was generally north of 72°N for much of late September, this region was not surveyed and there is no way to confirm whether bowheads were there.

Underwater blows were seen among feeding whales on three of five occasions in 1986. Würsig et al. (1985) suggest that underwater blows are associated with socializing whales, and in 1980 and 1981 they seemed correlated with feeding whales. Underwater blows have been associated with aggressive behaviors in humpback whales (Baker and Herman, 1984; Darling et al., 1983; Tyak and Whitehead, 1983), and with social groups of southern right whales (Clark, 1983). It is likely that feeding whales interact with conspecifics during feeding bouts and some of these interactions may be of an aggressive nature although it is not possible to strongly infer this from the small sample of observations.

A bowhead was observed playing with a log in waters northeast of Barter Island on 11 September (Appendix A, N780: Flight 23). The whale seemed to be a juvenile as it was slightly greyish in coloration and was estimated to be about 13-m long. Over a 10-minute period, the whale alternately nudged and partially submerged either end of a log estimated to be 8-m long. Twice it lifted the log with its head and let it roll across its back, then hit the log with its flukes. Although this is the first instance of log play noted in the Alaskan Beaufort Sea, several instances of similar activity were reported by Würsig et al. (1985) for bowheads summering in the Canadian Beaufort Sea.

Seven bowheads (4%) appeared to respond to the approach of the survey aircraft with a sudden change in behavior (Table 17). Positive responses were all from adult whales, and all but two were from whales in open water. Most whales (74%, n = 116) appeared to be unaffected by the aircraft and in some cases (22%, n = 35) whales were not observed long enough to determine if a behavioral change

Table 17. Semimonthly summary of bowhead response to aircraft, 1986.

	15-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-24 Oct No.(%)	Total No.(%)
Positive	2(5)	2(5)	1(2)	0	2(67)	7(4)
Negative	36(88)	23(58)	26(67)	30(86)	1(33)	116(74)
Unknown	3(7)	15(37)	12(31)	5(14)	0	35(22)
	41	40	39	35	3	158

had occurred. The mean aircraft altitude (1047 m) when bowheads responded was not significantly lower than that when whales did not appear to respond (1128 m, $t = 0.462$, $p < 0.32$).

Twelve sonobuoys were dropped during surveys, either near bowhead or gray whales or to monitor an area for bowhead calls (Table 18). Bowhead calls were recorded on only two occasions while conducting surveys. On 26 September a sonobuoy was dropped near two whales swimming north and west north of Harrison Bay (Appendix A, N780: Flight 14) and five calls were recorded (Table 19). Sixty-five calls were recorded on 12 October when a sonobuoy was dropped near two cow-calf pairs in waters northeast of Pt. Barrow. The calls were aurally analyzed (i.e., subjective listening) as in past years (Ljungblad et al., 1983, 1984a, 1986b) and placed into simple or complex moan categories. Simple moans were tonal, frequency-modulated (FM) sounds often with harmonic structure and usually in the 20-Hz to 2-kHz frequency band. Simple moans were classified to five categories based upon temporal frequency modulation as follows:

up	(FM_1)	=	ascending frequency modulation
down	(FM_2)	=	descending frequency modulation
constant	(FM_3)	=	no discernible frequency modulation
inflect	(FM_4)	=	combined ascending and decending frequency modulation
high	(FM_5)	=	short calls starting above 800 Hz

Complex moans were amplitude-modulated (AM) sounds. Amplitude modulation may be rapid resulting in well-defined components (Watkins, 1967), or slow,

Table 18. Summary of sonobuoy drops, 1986.

Date	A/C	Flt. No.	Latitude (N)	Longitude (W)	Subject
20 Aug	N780	6	70°29.3'	140°05.5'	Bowhead Whales
28 Aug	N780	10	70°13.2'	143°18.9'	Acoustic Monitor
3 Sep	N780	16	69°44.8'	139°13.4'	Bowhead Whales
11 Sep	N780	23	70°16.8'	142°32.1'	Bowhead Whales
15 Sep	N780	26	71°09.9'	157°39.9'	Gray Whales
26 Sep	N780	34	71°27.1'	151°55.8'	Bowhead Whales
2 Oct	N780	39	70°27.7'	164°12.7'	Gray Whales
6 Oct	302 EH	18	70°12.3'	143°35.3'	Acoustic Monitor
8 Oct	N780	43	71°40.7'	161°09.4'	Gray Whale
9 Oct	302 EH	20	70°10.3'	143°40.0'	Acoustic Monitor
10 Oct	302 EH	21	70°12.0'	143°36.5'	Acoustic Monitor
12 Oct	N780	45	71°38.4'	156°01.2'	Bowhead Whales

resulting in nonuniform and varied component structure. Two categories of complex moans aurally recognized on the basis of frequency content were

growl (AM_1) = low-frequency calls with energy primarily below 1 kHz

trumpet (AM_2) = high-frequency calls with energy primarily between 500 Hz and 4 kHz

Growls can (and do) grade into trumpets with a shift in frequency. Occasionally simple or complex moans exhibit both FM and AM components. Aurally these calls sound "complex" and were so categorized for the purpose of this analysis.

To standardize call counts over recording periods of varying duration, a call rate was derived as calls per whale-hour (calls/wh-h) by dividing the number of calls by the duration of the recording period and by the number of bowheads seen. Call rate, so derived, is useful only as a relative index of overall calling behavior because it's accuracy is dependent on a precise count of the number of whales near enough to the sonobuoy to be recorded. The whale-to-sonobuoy distance will vary somewhat with each location based upon sound propagation loss parameters that are dependent upon environmental factors such as water depth, ice cover, and sea state (Urick, 1983). An index of behavior was also derived to facilitate the

Table 19. Results of initial aural analysis of bowhead calls recorded via aircraft-deployed sonobuoys, 1986.

				CALL TYPE					
				SIMPLE			COMPLEX		
DATE	No. Whales	Behavior (Index)	Call Rate	UP No.(%)	DOWN No.(%)	CONST. No.(%)	GROWL No.(%)	TOTAL No.	COMMENT
26 Sep	2	SW (1.0)	10	1(20)	2(40)	0	2(40)	5	water noise
12 Oct	4	CC/BR (4.5)	32	9(14)	8(12)	1(2)	47(72)	65	belukha calls distant airgun
TOTAL	6	(3.3)	15.6	10(14.3)	10(14.3)	1(1.4)	49(70)	70	

integration of the 1986 call sample with data collated from prior years such that call samples recorded near whales involved in a variety of behaviors could be compared (Ljungblad et al., 1986b). The behavioral index was derived by ranking behaviors by their general surface activity level, then multiplying the rank by the number of surfaced whales seen within 10 km of the sonobuoy exhibiting that behavior and dividing by the number of whales. Behaviors were ranked and abbreviated as follows:

0 = resting (RE)
1 = swimming or diving (SW or DV)
2 = milling or mild social (ML or MS)
3 = feeding (FE)
4 = cow/calf association (CC)
5 = active social or play (AS or PL)
6 = display (DY)

These rankings attempted to reflect the relative level of exertion required of the whale involved in the behavior.

Of a call sample containing 70 discrete calls, 30 percent (n = 21) were simple moans and 70 percent (n = 49) were complex moans. Several call types (FM_4, FM_5 and AM_2) were not recorded, probably due to the small sample size. Calls recorded

Table 20. Summary of bowhead calf sightings, 1986.

Date	Aircraft	Flt	Latitude (°N)	Longitude (°W)	Heading (°M)	Behavior
15 Aug	N780	1	69°37.6'	140°48.6'	-	swimming with cow
20 Aug	N780	6	69°34.4'	139°30.8'	-	resting/swimming with cow
25 Sept	302EH	13	70°16.0'	142°44.4'	270°	swimming with cow
1 Oct	302EH	17	70°43.9'	149°38.4'	345°	swimming with cow
6 Oct	302EH	18	70°26.0'	147°35.9'	360°	swimming alone
6 Oct	302EH	18	70°24.5'	147°32.1'	130°	swimming alone
12 Oct	N780	45	71°38.3'	155°52.6'	230°	swimming with cow at surface
12 Oct	N780	45	71°37.7'	155°59.0'	230°	swimming near cow as cow breached

near the two swimming whales were mostly simple moans (60%, n = 3), while complex moans comprised most of the calls (70%, n = 49) recorded near the cow/calf pairs with one of the adults breaching. It appears that resting or swimming bowheads produce mostly tonal FM calls and that complex AM sounds are more commonly recorded near whales involved in social behaviors (Ljungblad et al., 1986b; Würsig et al., 1985). This assertion appears to be generally true of the 1986 call sample, although no significant correlations were found.

e. Calf Sightings and Estimated Recruitment

Eight calves were among the total of 158 bowheads seen, resulting in a GARR of 5.06 percent (Table 20). This estimate was nearly identical to that calculated for 1985 (5.04 percent), but higher than for any year except 1983 (7.56 percent). Two calves were seen in August among nearshore feeding aggregations. The calf seen on 15 August (Appendix A, N780: Flight 1) was very light gray which made it difficult to keep track of in the milky-green water where the whales were feeding.

This calf swam slowly alongside the cow, and the pair remained closer to the beach (150 to 200 m) than any of the other whales. On 20 August (Appendix A, N780: Flight 6) a darker calf was seen, also very near the beach, with a group of 19 feeding whales. This calf remained at the surface most of the time, but was joined by and swam short distances with a cow every 7 to 10 minutes. One calf was seen swimming northwest alongside a cow on 25 September (Appendix A, 302EH: Flight 13), and a second pair was observed swimming north on 1 October (Appendix A, 302EH: Flight 17). Two calves were seen swimming alone on 6 October (Appendix A, 302EH: Flight 18), and two cow-calf pairs were seen on 12 October (Appendix A, N780: Flight 45). One of the cows seen on 12 October breached repeatedly as it's calf swam just subsurface nearby. Many growl-like (AM_1) calls were recorded near the two cow-calf pairs, but no sounds attributable to the impact of the breaching whale was heard.

Gray Whale (*Eschrichtius robustus*)

a. Distribution

Fifty-seven sightings of 156 gray whales were made in the northeastern Chukchi and northwestern Alaskan Beaufort Seas in September and October (Table 7, Figure 16). There were 130 gray whales, including 1 calf, seen during September (Appendix A, N780: Flights 20 to 37) and 26 gray whales were seen during October (Appendix A, N780: Flights 38 to 52). Twenty-nine (19%) whales were seen in the northwestern Beaufort Sea, with the remaining 127 (81%) seen in the northeastern Chukchi Sea.

The distribution of gray whales was similar to that seen in past years with two exceptions. Gray whales (21 sightings of 60 whales) were seen consistently in block 14 farther offshore than gray whales had previously (1980-85) been seen during September and October (Moore et al., 1986a). Gray whales were seen in block 14 every time it was surveyed, with one exception, until the area was covered by 95 percent ice in mid-October. Additionally, gray whales were seen farther east in the Alaskan Beaufort Sea than before. With the exception of 3 gray whales seen by this project in the Canadian Beaufort in August 1980 (Rugh and Fraker, 1981), the farthest east sighting was at 71°28.6'N, 156°11.2'W in August 1983. In fall 1986, gray whales were seen farther east on two occasions: 6 whales were seen feeding northeast of Barrow on 7 September (Appendix A, N780: Flight 20) at 71°28.3'N, 156°07.5'W, and 1 whale was seen swimming southwest on 19 September (Appendix A, N780: Flight 29) at 71°32.9'N, 155°44.5'W.

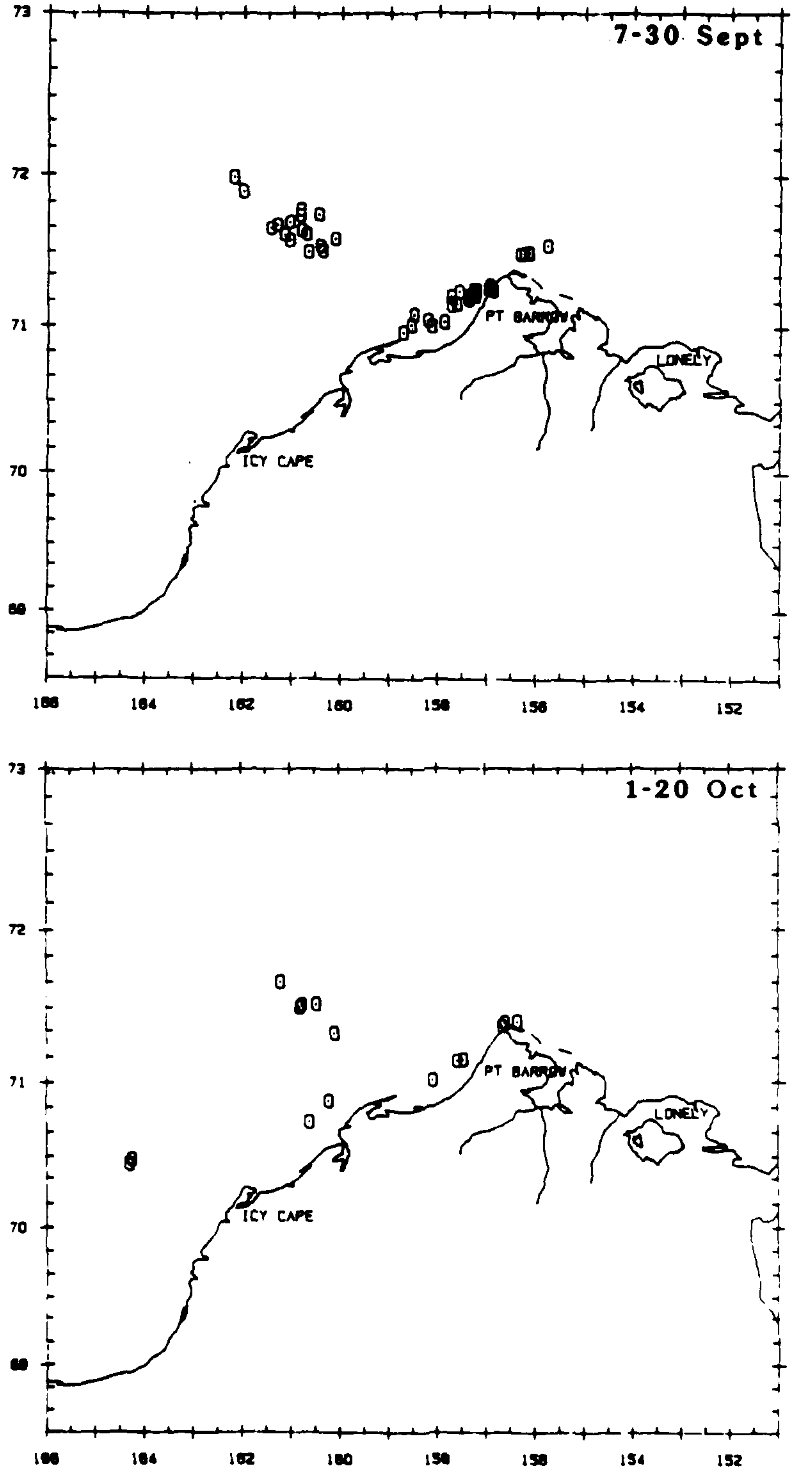


Figure 16. Distribution of 57 sightings of 156 gray whales in the northeastern Chukchi and northwestern Alaskan Beaufort Seas: 7-30 September; 1-20 October, 1986.

Table 21. Relative abundance (WPUE = no. whales/hours of survey effort) of gray whales by survey block, 1986.

	SEPTEMBER			OCTOBER			TOTAL		
BLOCK	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE
12	**4.40**	**26**	**5.91**	12.09	3	0.25	16.49	29	1.76
13	15.57	56	3.60	15.71	6	0.38	31.28	62	1.98
14	9.30	48	5.16	**7.80**	**12**	**1.54**	**17.10**	**60**	**3.51**
15	6.45	0	0	0.39	0	0	6.84	0	0
16	0.44	0	0	0	0	0	0.44	0	0
17	6.68	0	0	7.35	2	0.27	14.03	2	0.14
18	3.08	0	0	2.70	3	1.11	5.78	3	0.52
20	3.55	0	0	0.05	0	0	3.60	0	0
22	0.80	0	0	0	0	0	0.80	0	0
TOTAL	50.27	130	2.59	46.09	26	0.56	96.36	156	1.62

Bold indicates peak WPUE.

b. Relative Abundance and Density Estimates

Areas of greatest gray whale relative abundance were blocks 14, 13, and 12, where WPUE was 3.51, 1.98, and 1.76 respectively (Table 21). Whales in block 14 were between 55 and 166 km offshore. Those seen in block 13 were between Pt. Barrow and Pt. Franklin from 0.5 to 33 km from shore. Whales seen in block 12 were just north and northeast of Pt. Barrow. Two gray whales were seen in block 17 between 15 and 20 km off of Wainwright, and three were seen 90 km offshore of Icy Cape in block 18.

Estimates of gray whale density in September were 0.63 whales/100 km^2 in block 14 and 0.23 whales/100 km^2 in block 13 (Figure 17). In October, the highest density estimate was in block 18 (0.20 whales/100 km^2). The highest seasonal density estimate was in block 14 at 0.36 whales/100 km^2. The unusually high relative abundance and density estimates calculated for block 14 correspond with the high incidence of grays feeding there in 1986. Surprisingly, the September-October density estimates were higher than those calculated for the survey blocks in July 1985 (Ljungblad et al., 1986b). These estimates represent densities of

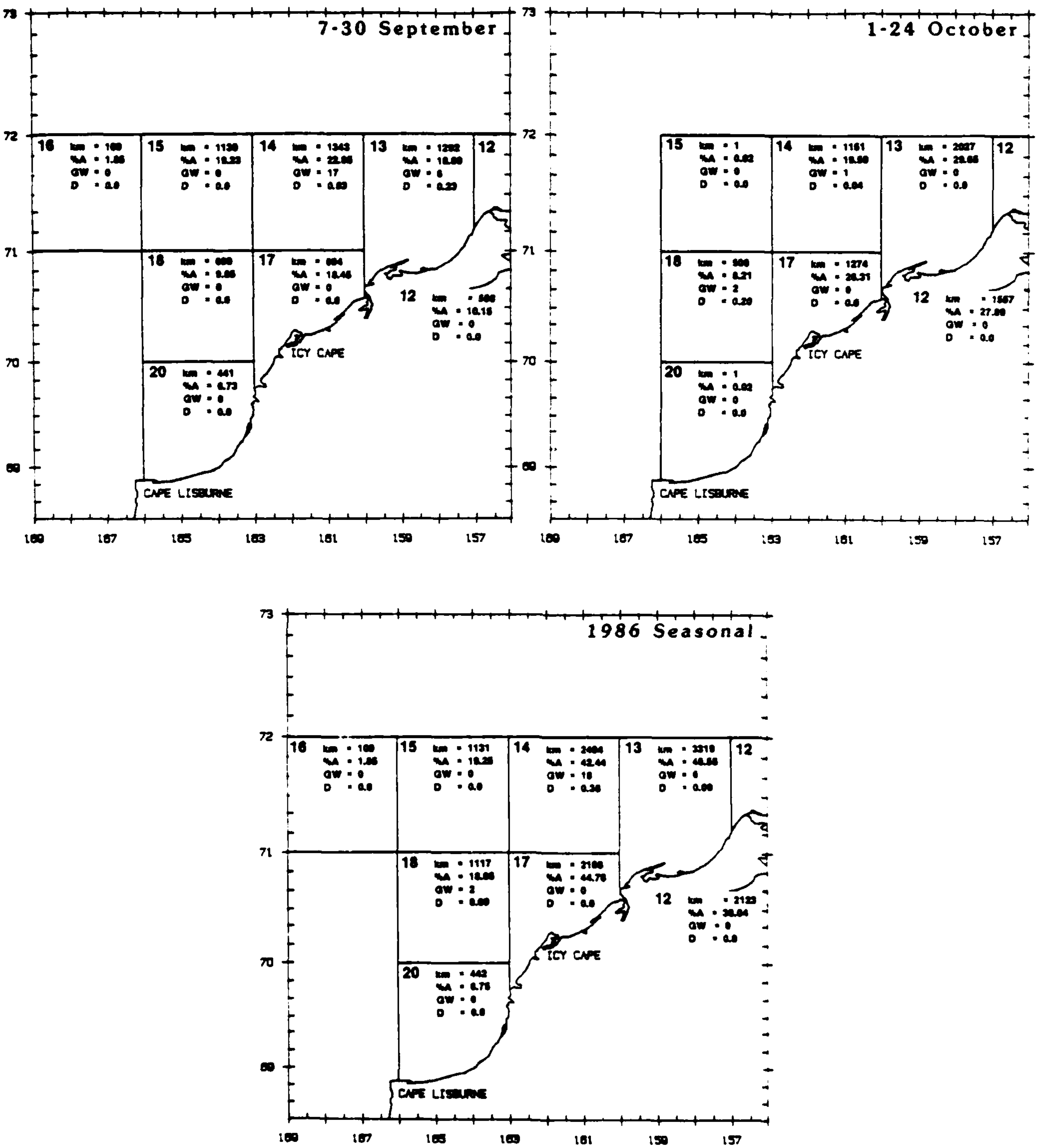


Figure 17. Monthly and seasonal gray whale density by block, 1986.

Table 22. Observed gray whale behavior by sea, 1986.

BEHAVIOR	Chukchi Sea No.(%)	Beaufort Sea No.(%)	Total No.(%)
Swim	15(12)	5(17)	20(13)
Dive	1 (1)	0	1 (1)
Rest	4 (3)	0	4 (2)
Feed	102(80)	24(83)	126(81)
Display	1 (1)	0	1 (1)
Mate	3 (2)	0	3 (1)
None recorded	1 (1)	0	1 (1)
TOTAL	127	29	156

whales at the surface only and were not corrected for submerged whales. Additional gray whale density estimates for coastal and offshore regions in the northeastern Chukchi Sea are presented in Appendix B.

c. Habitat Relationships and Behavior

Gray whales in the Chukchi Sea were seen approximately 0.5 to 166 km offshore in water 18- to 51-m deep ($\bar{x}$ = 32.8, s.d. = 10.86, n = 46) and were approximately 0.5 to 41 km from shore in water 5- to 18-m deep ($\bar{x}$ = 9.4, s.d. = 4.52, n = 11) in the northwestern Alaskan Beaufort Sea. Gray whales were never seen associated with ice, unlike past years. After the formation of the ice in mid-October, they were seen only south of the ice edge, even though numerous flights were made into areas heavily covered with ice. Gray whales were seen consistently in block 14 each time the block was traversed until mid-October, when 95 percent new ice existed.

Gray whales were usually seen feeding (81%, n = 126) in both the northeastern Chukchi (n = 102) and northwestern Beaufort (n = 24) Seas (Table 22). Feeding was inferred anytime a whale was seen with a mud plume. Mud plumes, billows of sediment brought to the surface by whales feeding on infaunal prey, are excellent sighting cues and may positively bias data toward "feeding" whales. Conversely, whales feeding on epibenthic prey may not create mud plumes and therefore some "feeding" whales may go unrecorded. The gray whales seen in block 14 brought large plumes of sediment to the surface indicating that they were feeding on infaunal prey. Although this area of the Chukchi Sea has not been directly sampled, the prey likely consists of mixed crustacean communities including the

Ampelisca amphipods that constitute much of the gray whale diet in the northern Bering Sea (J. Oliver, personal communication[6]).

Gray whales not feeding were seen swimming (13%, n = 21), resting at the surface (2%, n = 4), diving (1%, n = 1), breaching (1%, n = 1), and mating (2%, n = 3). The three gray whales involved in mating behavior were observed on 7 September (Appendix A, N780: Flight 20) at 71°12.0'N, 157°21.6'W. The whales were positively identified as engaged in sexual behavior due to repeated sightings of a penis. The whales created a large water disturbance (which was the first sighting cue) and much rolling and flipper and tail slapping accompanied the display. The sexual behavior continued from the time of initial sighting for an additional 11 minutes, at which time the whales dispersed, with two swimming together heading northeast and one swimming southwest. Other gray whales (n = 9), all feeding, were in the same general area. The original sighting was made at an altitude of 320 m (1050 ft), and the whales showed no response to the aircraft. To our knowledge, this observation represents the northern extreme of reported mating activity in gray whales. The only other sighting was that of "possible mating activity of 2 to 3 whales" within a group of nine whales that included a calf seen on 25 July 1981 near Icy Cape (approx. 70°21.9'N, 160°48.8'W; Ljungblad, unpub. data). In general, gray whale courtship and mating behavior is thought to be confined to their southern range (Swartz, 1986).

Gray whales exhibited headings in all directions. Headings were not recorded for whales considered feeding, since those whales often exhibited numerous headings within one surfacing period.

Average group size for all gray whales was 4.41 (s.d. = 2.41, n = 29). Group size was larger in the Beaufort ($\bar{x}$ = 5.50, s.d. = 5.00, n = 4) than in the Chukchi ($\bar{x}$ = 4.24, s.d. = 1.85, n = 25), but this difference was not significant (t = 0.969, df = 27, $p < 0.17$). Groups of feeding gray whales ($\bar{x}$ = 4.91, s.d. = 2.45, n = 23) were significantly larger than groups of nonfeeding gray whales ($\bar{x}$ = 2.50, s.d. = 0.84, n = 6; t = 2.35, df = 27, $p < 0.01$).

Gray whale carcasses were seen on two consecutive days in September (Appendix A, N780: Flights 29 and 30). The first carcass was located at 71°31.0'N, 157°13.3'W, and was partially decomposed with numerous birds on and around it. The second carcass sighting was at 71°46.2'N, 161°38.9'W, also partially decomposed. Positive cause of mortality could not be determined in either case due to the state of decomposition.

d. Calf Sightings and Estimated Recruitment

One gray whale calf was seen on 7 September (Appendix A, N780: Flight 20) north of Pt. Barrow. The calf was within a group of 12 adult whales feeding in shallow (9 m) water. Gray whale calves have been seen in the Chukchi Sea in past years, often in greater relative numbers than in the northern Bering Sea (Moore et al., 1986b). Except for one calf seen in block 13 on 17 August 1983 (Ljungblad et al., 1984a), gray whale calves have been seen in the Chukchi Sea only in July.

Other Marine Mammals

a. Belukha, or White Whale (Delphinapterus leucas)

There were 109 sightings of 492 belukhas made in the Alaskan Beaufort and northeastern Chukchi Seas in fall (Figure 18). Also, 453 belukhas, including 40 calves, were seen in the Beaufort Sea, and 39, including 4 calves, were seen in the Chukchi Sea. The distribution of belukhas in both seas was similar to that of past years.

Areas of greatest relative abundance in the latter half of August were blocks 9, 6 and 8, where WPUE was 6.98, 3.81 and 3.63 respectively (Table 23). In September, blocks 2 and 9 had the highest WPUE (14.93 and 9.97 respectively), and other offshore blocks (10 and 11) also had relatively high WPUE. In October, block 9 again had the highest WPUE, with 34 belukhas seen in 0.14 hours for a WPUE of 242.86. Blocks 12, 11, and 2 also had high WPUE during October. Overall, blocks 9 (14.39) and 2 (8.90) had the highest WPUE for the season.

Belukhas in the Beaufort Sea were seen approximately 0.5- to 231-km from shore in water 7- to 3255-m deep ($\bar{x}$ = 692.7, s.d. = 882.7, n = 99) and approximately 29 to 143 km from shore in water 26- to 183-m deep ($\bar{x}$ = 64.9 s.d. = 46.2, n = 10) in the northeastern Chukchi Sea. Belukhas were seen in ice cover ranging from 0 to 95 percent (Table 24) and were generally seen in whatever ice conditions prevailed; lighter ice (0 to 30%) during August and September (n = 242, 86%), and both heavy (71 to 100%) and light ice in October (n = 201, 95%). Few (8%, n = 40) were seen in intermediate ice cover areas (31 to 70%).

The majority of belukhas (95%, n = 469) seen were swimming. Other behaviors included resting (4%, n = 21) and milling (< 1%, n = 2). Forty-four calves were seen among 492 adults, for a GARR of 8.94%. Belukhas were seen both singly and in groups of 2 to 66 ($\bar{x}$ = 7.60, s.d. = 10.96, n = 58). Three carcasses were seen floating in the Chukchi Sea.

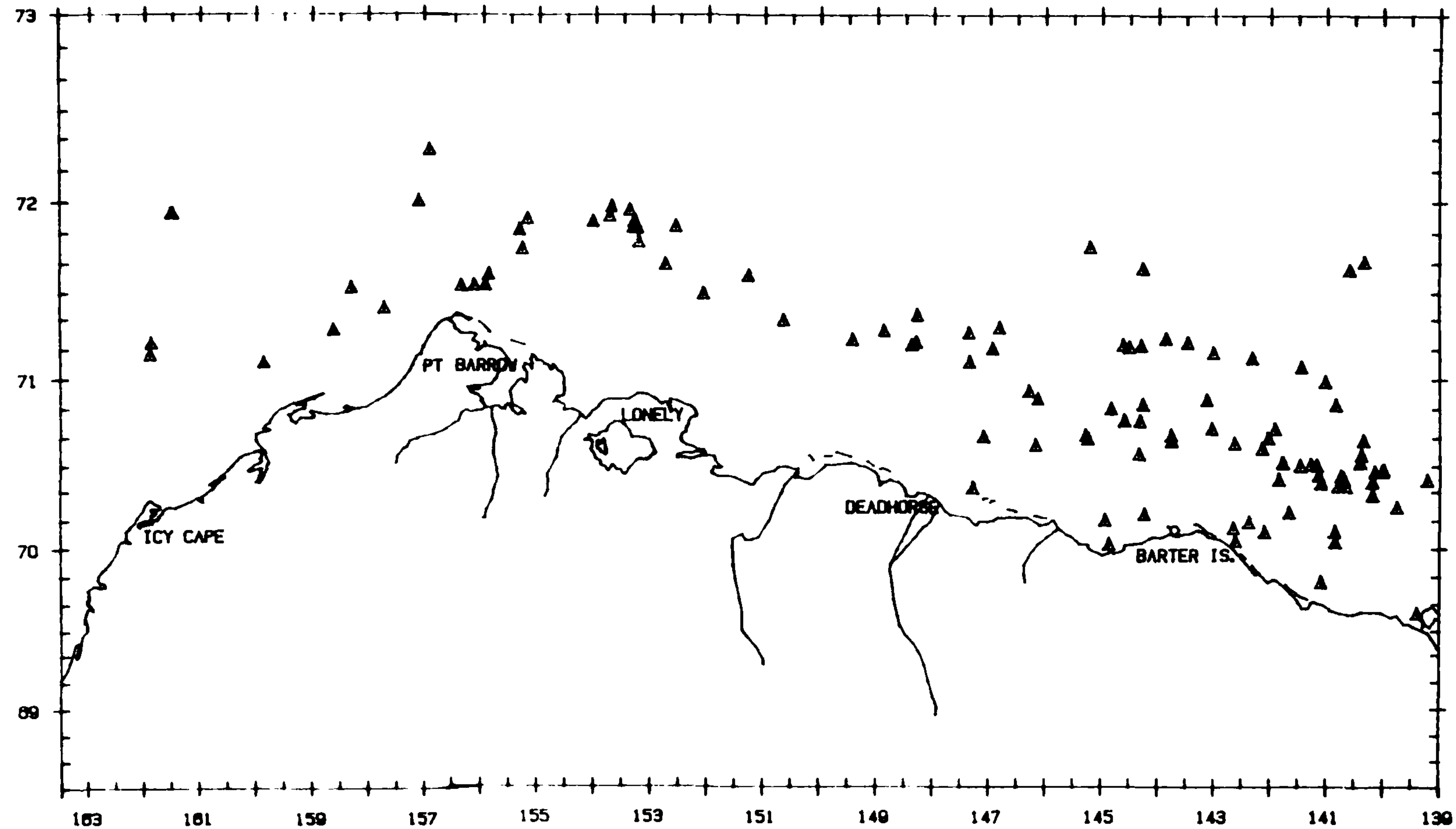


Figure 18. Distribution of 109 sightings of 492 belukhas, 1986.

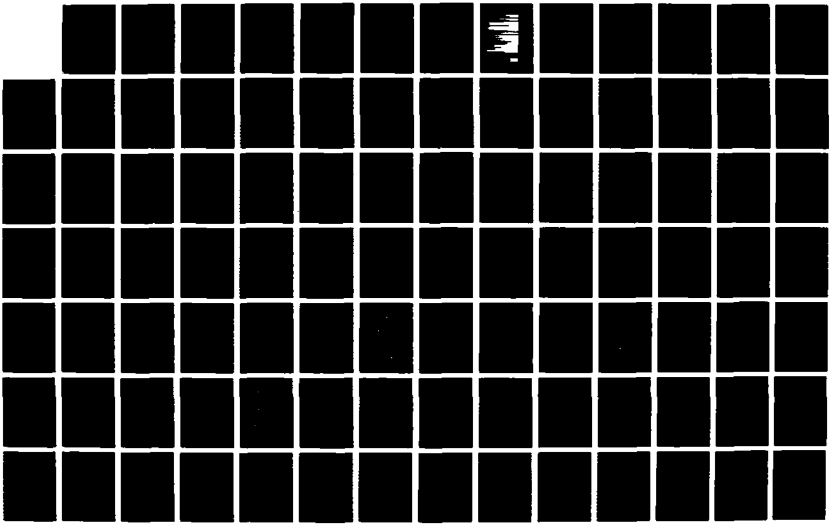
Table 23. Monthly and seasonal relative abundance of belukhas (WPUE = no. whales/hours of survey effort) by survey block, 1986.

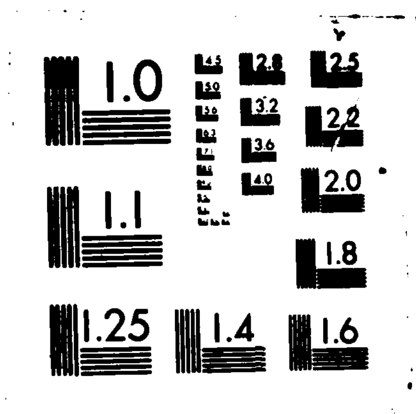
	AUG		SEPT		OCT		TOTAL	
BLOCK	BE	WPUE	BE	WPUE	BE	WPUE	BE	WPUE
1	0	0	8	0.39	0	0	8	0.21
2	0	0	**70**	**14.93**	19	3.58	89	8.90
3	0	0	0	0	2	0.23	2	0.1[illegible]
4	1	0.08	3	0.18	0	0	4	0.12
5	14	1.05	50	2.80	0	0	64	2.06
6	26	3.81	4	0.39	0	0	30	1.53
7	9	2.02	5	0.51	0	0	14	0.98
8	12	3.63	0	0	0	0	12	2.02
9	**18**	**6.98**	29	9.97	**34**	**242.86**	**81**	**14.39**
10	0	0	13	6.47	0	0	13	5.88
11	0	0	13	5.91	18	4.74	31	5.17
12	0	0	0	0	100	8.27	100	6.06
13	0	0	0	0	29	1.85	29	0.93
14	0	0	1	0.11	8	1.03	9	0.53
15	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
[illegible]	0	0	0	0	0	0	0	0
[illegible]	0	0	0	0	0	0	0	0
[illegible]	0	0	0	0	1	0.28	1	0.18
[illegible]	1	0.74	4	2.45	0	0	5	1.68
	81	1.73	200	1.33	211	2.36	492	1.71

[illegible] WPUE.

AD-A183 934 DISTRIBUTION ABUNDANCE BEHAVIOR AND BIOACOUSTICS OF ENDANGERED WHALES IN T..(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA D K LJUNGBLAD ET AL. JUL 87 NOSC/TR-1177 2/5

UNCLASSIFIED F/G 8/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table 24. Number (No.) and percent (%) of belukhas found in each ice cover class, 1986.

Ice Cover (%)	15-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-24 Oct No.(%)	Total No.(%)
0-10	27(33)	71(85)	103(89)	124(70)	0	325(66)
11-20	0	0	11 (9)	1 (1)	0	12 (2)
21-30	17(21)	13(15)	0	5 (3)	0	35 (7)
31-40	0	0	1 (1)	3 (2)	0	4 (1)
41-50	12(15)	0	1 (1)	0	0	13 (3)
51-60	16(20)	0	0	0	1 (3)	17 (3)
61-70	0	0	0	0	6(17)	6 (1)
71-80	9(11)	0	0	34(19)	21(60)	64(13)
81-90	0	0	0	9	4(11)	13 (3)
90-100	0	0	0	0 (5)	3 (9)	3 (1)
TOTAL	81	84	116	176	35	492

Belukhas were not clustered around any particular heading until September, when there was significant clustering in the Beaufort Sea around 259°T ($z = 5.12$, $n = 38$, $p < 0.005$). In October, there was significant clustering in the Beaufort Sea around the same heading (259°T; $z = 4.26$, $n = 22$, $p < 0.01$). Those in the Chukchi Sea were not significantly clustered around any particular heading.

Belukhas in the Beaufort Sea were found in significantly deeper water ($\bar{x} = 692.7$m, s.d. = 882.7, $n = 99$) than were bowheads ($\bar{x} = 50.6$m, s.d. = 102.9, $n = 104$) throughout fall ($t = 7.37$, $p < 0.001$).

b. **Narwhal (Monodon monceros)**

Two narwhals were seen during surveys flown in support of bowhead-tagging studies in the Canadian Beaufort Sea. The first narwhal was seen on 31 August at 69°18.9'N, 138°40.9'W near the beach at Stokes Point. The animal appeared to be a mottled brown and had a distinctive tusk estimated to be 1.25-m (4 ft) long. After several minutes of observation, the whale dove and was not resighted. On 5 September a second narwhal was seen swimming east (90°T) just west of Herschel Island at 69°34.1'N, 139°22.5'W. This whale appeared dark grey in color and was estimated to be 2.8 to 3.1 m (9 to 10 ft) in body length with a 1.25-m tusk. This whale also dove after a brief period of observation and was not resighted. A female narwhal was also sighted near Herschel Island by the crew of another survey

aircraft (J. Ford, personal communication[7]). Narwhals are uncommon in the western Canadian arctic (Reeves and Tracey, 1980), with the first reported occurrence that of a tusk and cranium found in Prince Albert Sound (71°22'N, 117°21'W; Smith, 1977). Narwhals are occasionally seen in Alaskan waters, with several sightings reported across the north coast (Reeves, 1978) and at least one sighting of two males in the northern Bering Sea (Ljungblad et al., 1983).

c. Unidentified Cetaceans

There were four sightings of five unidentified cetaceans made during September and October; all were in the Chukchi Sea. The first was on 14 September (Appendix A, N780: Flight 25) at 69°30.2'N, 164°39.3'W. The animal, which appeared to be medium-sized, dark and with a dorsal fin, was seen only briefly and was swimming fast. Due to deteriorating weather conditions, the sighting was made while the aircraft was at a relatively low altitude (207 m) and the animal was not resighted. Medium-sized whales with dorsal fins that have been previously documented in the Chukchi Sea include only the killer whale (*Orcinus orca*) and the minke whale (*Balaenoptera acutorostrata*) (Leatherwood et al., 1982).

Two unidentified cetaceans were seen briefly on 24 September (Appendix A, N780: Flight 32) at 69°59.0'N, 161°05.0'W. They dove immediately and were not resighted, even though the area was thoroughly searched. Two more unidentified cetaceans were seen on 21 October (Appendix A, N780: Flight 53): one at 70°55.8'N, 159°15.5'W and one at 70°11.5'N, 163°14.7'W. Both were sighted when the aircraft was at relatively low altitude (192 m and 162 m respectively), and no positive identification could be made. These sightings were probably of bowheads or gray whales.

d. Walrus (*Odobenus rosmarus*)

One-hundred-nineteen walruses were seen in the Chukchi Sea throughout September and October (Figure 19). Most were swimming; only one group of 14 animals was seen hauled out on the ice (Appendix A, N780: Flight 43). Three walruses, all swimming, were seen in the western Alaskan Beaufort Sea in mid-September (Appendix A, N780: Flights 24 and 29). Most walruses (92%, n = 112) were seen in open water (< 10% ice cover). Four walrus carcasses were seen, three in the Chukchi and one in the Beaufort. All of the carcasses were floating, and were badly decomposed and bloated. Cause of death could not be positively determined.

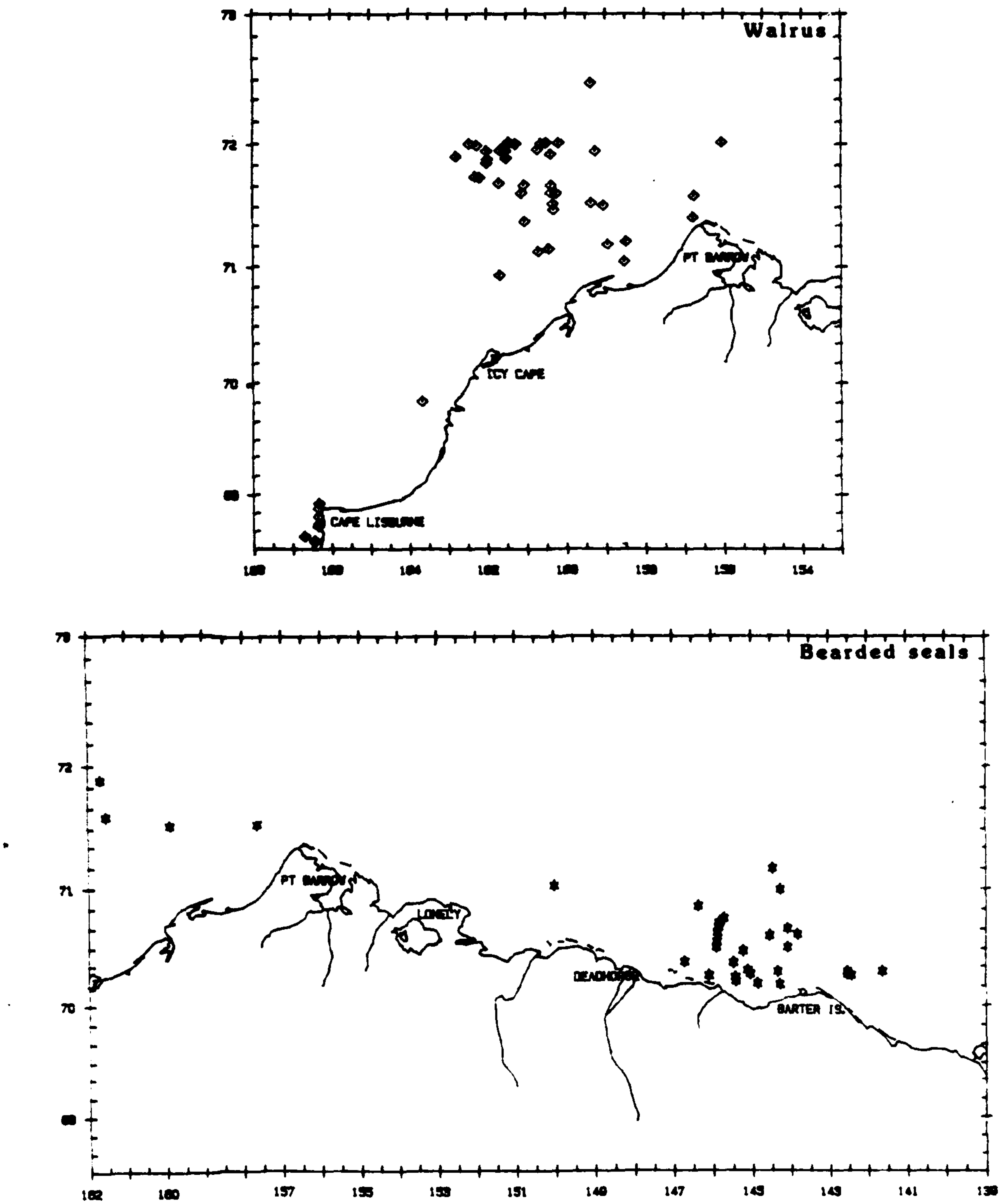


Figure 19. Distribution of walruses, bearded seals.

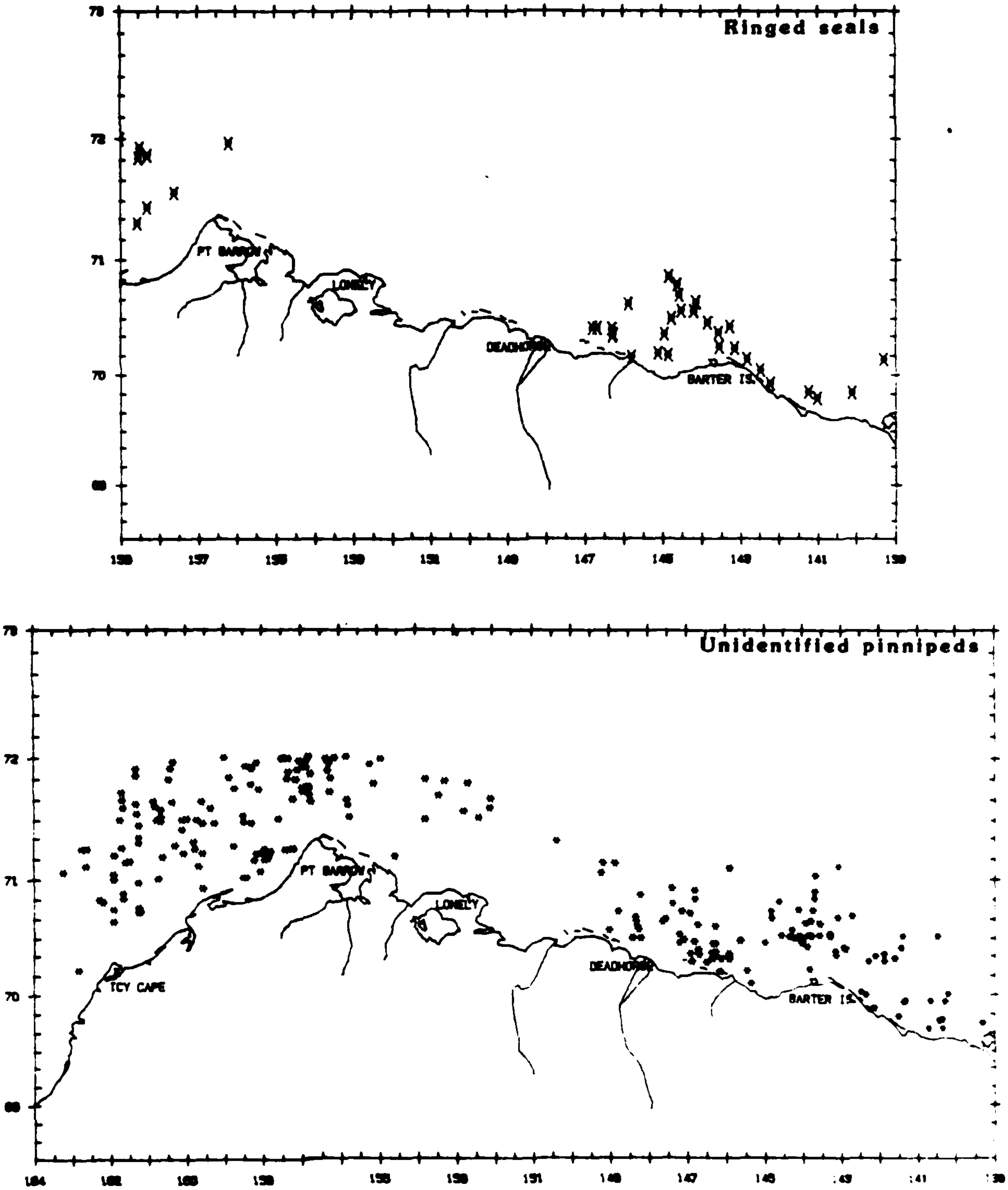


Figure 19 (contd). ringed seals, and unidentified pinnipeds, 1986.

e. **Bearded Seal (Erignathus barbatus)**

Thirty-eight bearded seals were seen in the Beaufort Sea from August to September (Figure 19), mostly clumped north of Camden Bay. Four were seen in the Chukchi Sea in late September and October. Most bearded seals (86%, n =36) were swimming in areas of light to medium ice.

f. **Ringed Seal (Phoca hispida)**

One hundred four ringed seals were seen in the Beaufort Sea and 19 were seen in the Chukchi Sea from mid-August to mid-September (Figure 19). Ringed seals were observed in two areas: east of 147°W (84%, n = 103) and west of 156°W (16%, n = 20). All of the ringed seals west of 156°W were seen on one flight (Appendix A: N780, Flight 29). The apparent clumped distribution of ringed seals may actually be due to the difficulty in positively identifying pinnipeds from altitudes of 305 to 457 m (1000 to 1500 ft), resulting in much higher tallies of unidentified pinnipeds.

g. **Unidentified Pinnipeds**

Three hundred forty unidentified pinnipeds were seen in the Beaufort Sea and 145 in the Chukchi Sea from mid-August through October (Figure 19). In August and early September most seals were seen swimming, while in the latter half of September and throughout October most seals were hauled out on the ice near breathing holes. Pinnipeds were not seen in appreciable numbers (3%, n = 16) in blocks 3 and 11, encompassing Harrison and Smith Bays, as they were in 1982-84 (Ljungblad et al., 1983, 1984a, 1985a). While this may have been due to prevailing open water conditions and/or availability of food elsewhere, it also may be because less survey effort was spent in 1986 (11%) in those two blocks than in previous years.

h. **Polar Bears (Ursus maritimus)**

Eleven sightings of 15 polar bears were made during survey flights in fall (Table 25). Two polar bears were seen in August in the eastern Alaskan Beaufort Sea. Three bears, including a sow and young cub, were seen in the Beaufort Sea in September (Appendix A, N780: Flight 28). The remaining 10 polar bears were all seen during the latter half of October in both the Beaufort and Chukchi Seas. All but one were seen in heavy ice (>85% ice cover); one bear was seen swimming in 5% ice cover.

Three polar bears, one adult and two juveniles, were seen on 12 October at approximately 70°07'N, 143°35'W, during a nonsurvey flight to ferry equipment between Deadhorse and Barter Island.

Table 25. Summary of polar bear sightings, 1986.

Date	Flt	Aircraft	Number	Latitude(N)	Longitude(W)
17 Aug	3	N780	1	70°19.5'	146°51.9'
24 Aug	7	N780	1	70°13.9'	141°50.1'
17 Sept	28	N780	1	70°19.0'	147°04.0'
17 Sept	28	N780	2	71°17.5'	146°04.0'
15 Oct	47	N780	1	71°59.7'	159°31.1'
19 Oct	51	N780	1	71°50.5'	156°19.0'
20 Oct	52	N780	1	71°45.7'	157°22.8'
20 Oct	52	N780	2	71°42.6'	158°04.6'
23 Oct	54	N780	1	71°26.3'	154°29.1'
24 Oct	55	N780	2	71°11.1'	159°40.2'
24 Oct	55	N780	2	71°11.2'	158°04.8'

Acoustic Monitoring in the Eastern Alaskan Beaufort Sea

Recording Effort, Rationale and Daily Summary

The acoustic monitoring study conducted near Barter Island proved successful in establishing the feasibility of using passive acoustics to detect bowhead whales during the fall migration. Over 590 hours of recordings were made on 42 days between 25 August and 11 October (Figure 20), either from expendable sonobuoys with an 8-hour life or from specially modified sonobuoys with an extended transmission life of about 72 hours. Both the expendable and modified sonobuoys were equipped with omnidirectional hydrophones that were sensitive to bowhead call frequencies, but provided no directional information.

Efforts were made to monitor and record the underwater acoustic environment offshore Barter Island around the clock. To this end, sonobuoy systems that had lost power or been destroyed by ice were replaced as soon as conditions permitted. The shorebased recording station was maintained in the crews' quarters such that data were often listened to as they were being recorded. A daily written log was maintained to summarize the type of ambient, industrial or biological data recorded, and to note local weather and ice conditions. An abbreviated summary of the daily acoustic log (Table 26) highlights the salient environmental and acoustical events.

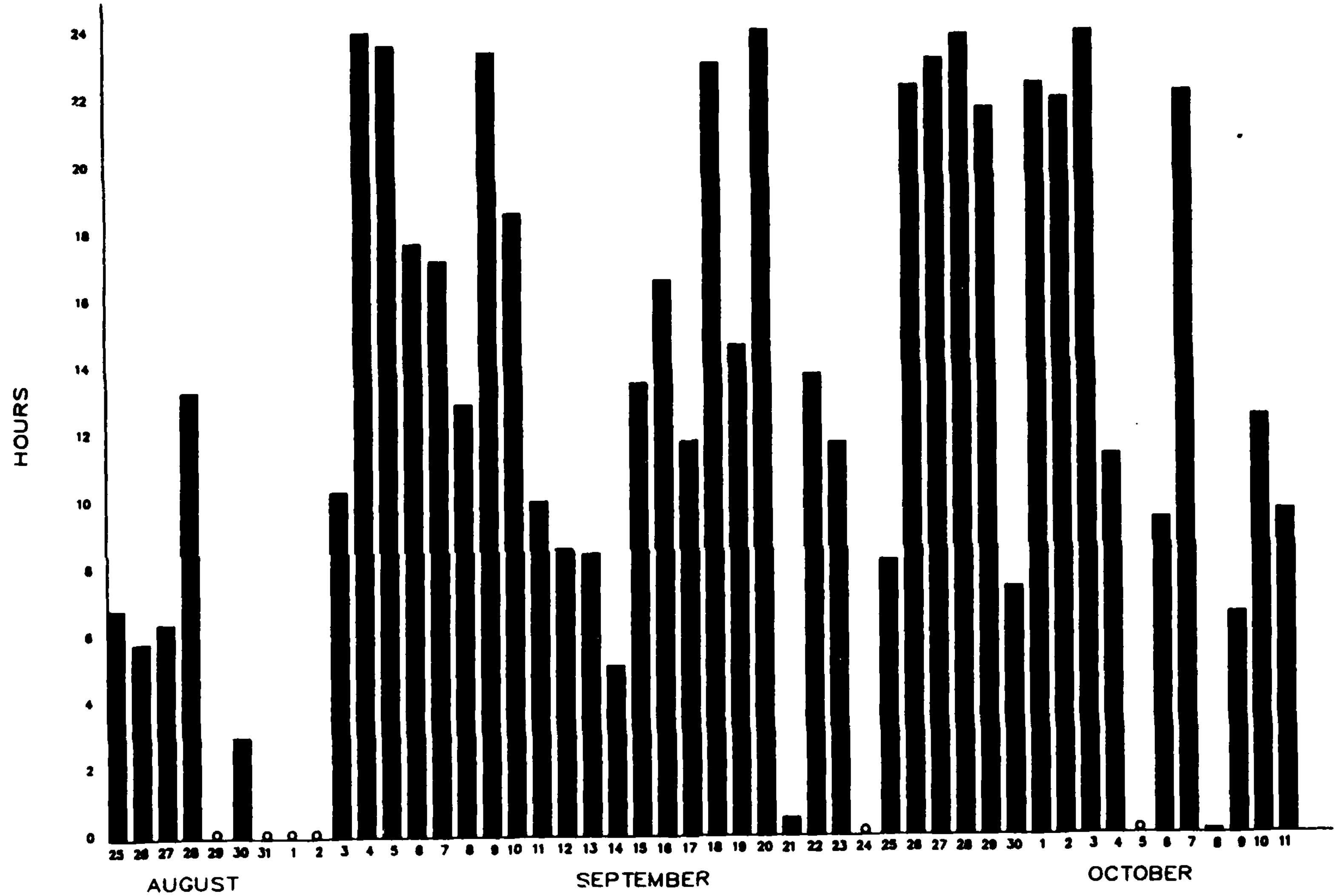


Figure 20. Histogram depicting hours of recording effort at the Barter Island acoustic station.

Table 26. Daily summary of acoustic and environmental conditions (ice cover, beaufort sea state, temperature) at the acoustic monitoring station on Barter Island, 1986.

Date	Acoustic Data	Environmental Summary*		
25 Aug	Ambient ice and sea noise	IC=25-50%;	B2-3;	-1°C
26 Aug	Ambient ice and sea noise	IC=25-45%;	B2-3;	-0.5°C
27 Aug	3 seal "barks" ambient ice and sea noise	IC=20-45%;	B3-4;	1°C
28 Aug	Ambient sea noise, outboard motor, seismic sounds	IC=20-45%;	B4-5;	0°C
29 Aug	Quiet ambient sea noise	IC=15-45%;	B4-5;	2°C
30 Aug	Quiet ambient sea noise, outboard motor, distant seismic sounds	IC=10-45%;	B2-3;	8°C
31 Aug	No sonobuoy	IC=0-45%;	B2-3;	2°C
1 Sep	No sonobuoy	IC=0-30%;	B2-4;	6°C
2 Sep	Quiet ambient, some outboard motor noise	IC=0-10%;	B1-3;	5°C
3 Sep	First Bowhead call, Belukha calls and distant bearded seal trills. Some outboard and distant seismic sounds	IC=0-7%;	B2-3;	12°C
4 Sep	Quiet ambient sea noise, some outboard motor and seismic sounds, distant bearded seals	IC=0-5%;	B1-3;	18°C
5 Sep	Quiet ambient sea noise, seismic sounds and occasional outboard noise	IC=0-5%;	B2-4;	7°C
6 Sep	Quiet ambient sea noise and seismic sounds	IC=1-5%;	B1-3;	11°C
7 Sep	Quiet ambient sea noise, seismic sounds and occasional outboard noise	IC=0-2%;	B0-4;	7°C
8 Sep	Quiet ambient sea noise, distant seismic sounds, some outboard noise	IC=0-2%;	B1-4;	4°C
9 Sep	Two distant Bowhead FM calls, quiet ambient sea noise, seismic sounds	IC = 0%;	B2-4;	6°C
10 Sep	Ambient ice and sea noise, seismic sounds and some outboard noise	IC = 0%;	B3-4;	6°C
11 Sep	Single Bowhead call, ice and ambient sea noise, some seismic sounds	IC = 0%;	B3-4;	3°C
12 Sep	Ambient sea and ice noise	IC = 0%;	B2-4;	2°C
13 Sep	Ice noise, some outboard motor noise	IC = 0%;	B3-4;	3°C
14 Sep	Ambient sea noise, inboard motor noise	IC=0-5%;	B1-2;	7°C
15 Sep	Quiet ambient sea noise	IC=0-5%;	B2-5;	10°C
16 Sep	Distant Belukha calls, loud ambient ice and sea noise	IC=0-3%;	B2-3;	7°C

Table 26 (contd).

Date	Acoustic Data	Environmental Summary*		
17 Sep	Belukha calls, outboard noise, ambient sea noise	IC=0-5%;	B2-4;	4°C
18 Sep	Ambient sea noise	IC=0-7%;	B2-4;	8°C
19 Sep	Ambient sea noise	IC=0-10%;	B3-4;	4°C
20 Sep	Ambient sea noise (loud)	IC=0-10%;	B3-4;	4°C
21 Sep	Ambient sea noise	IC=0-7%;	B2-4;	4°C
22 Sep	Ambient sea noise (loud)	IC=0-5%;	B6-7;	0.5°C
23 Sep	Ambient sea noise	IC=0-3%;	B5-7;	-1°C
24 Sep	No Sonobuoy	IC=0-2%;	B2-4;	-0.5°C
25 Sep	Bearded seal trills, seismic sounds, ambient sea noise	IC = 0%;	B2-3;	0.5°C
26 Sep	Bearded seal trills, outboard motor, distant seismic sounds	IC = 0%;	B3-4;	-0.5°C
27 Sep	661 Bowhead calls, bearded seal trills, seismic and outboard noise	IC = 0%;	B2-3;	-4°C
28 Sep	2100 Bowhead calls, bearded seal trills, seismic and vessel noise	IC = 0%;	B4-6;	-4°C
29 Sep	5343 Bowhead calls, bearded seal trills	IC=0-3%;	B4-5;	-2°C
30 Sep	55 Bowhead calls, seismic and vessel noise	IC=0-5%;	B6-8;	-2°C
1 Oct	1566 Bowhead calls, bearded seal trills, outboard, seismic and vessel noise	IC=0-3%;	B2-4;	-5°C
2 Oct	1373 Bowhead calls, bearded seal trills, loud seismic, ambient sea noise	IC=0-3%;	B2-3;	-3°C
3 Oct	375 Bowhead calls, seismic sounds, ambient sea noise	IC=0-5%;	B4-7;	-3°C
4 Oct	Ambient sea noise, seismic sounds H-phone line cut by ice	IC=0-5%;	B6-7;	-4°C
5 Oct	No sonobuoy	IC=0-5%;	B3-4;	-12°C
6 Oct	131 Bowhead calls, ambient sea noise, vessel and seismic sounds	IC=0-10%;	B4-5;	-4°C
7 Oct	Ambient ice and sea noise	IC=10-30%;	B4-5;	-4°C
8 Oct	Ambient ice and sea noise	IC=20-45%;	B4-5;	-7°C
9 Oct	Ambient ice and sea noise	IC=25-50%;	B4-5;	-16°C
10 Oct	Ambient ice and sea noise	IC=30-80%;	B3-4;	-3°C
11 Oct	Ambient ice and sea noise, terminated study due to ice build up	IC=50-85%;	B2-3;	-3°C

*IC = ice cover
B = Beaufort scale sea state
°C = air temperature at ca. 1200 hrs in °Centigrade

Sound Propagation in the Study Area

The ability to record bowhead calls throughout the field season was affected by the environmental features limiting sound propagation in the study area. Transmission loss (TL) is a term that summarizes the loss of signal strength with distance from the source due to attenuation and spreading (Urick, 1983). Spreading loss describes the geometric weakening of a signal with distance, while attenuation is the loss of signal due primarily to absorption and scattering.

Local bathymetry and water temperature are two important features which effect sound attenuation loss. A sound that may travel over long distances in deep water can be attenuated over relatively short distances in shallow water due to absorption and scattering of the sound at the sea bottom and surface. Variation in temperature (as well as salinity and pressure) through the water column affects the velocity of sound such that a signal travels at different speeds at different depths. The effect of a water column temperature gradient, and its concomitant variation in sound velocity, is to deflect a signal propagating through that medium. Basically, a signal passing through a water column of varying temperatures can be depicted as a sound ray that is multiply deflected either toward the surface or toward the bottom as it encounters the temperature (velocity) interfaces. Sound ray paths that deflect a signal to the surface will increase transmission loss due to scattering by waves or ice, while sound rays deflected downward will increase transmission loss due to absorption and scattering from the bottom. A thorough presentation of transmission loss, sound velocity and sound ray paths is presented in Urick (1983, pp. 99-128).

Local bathymetry and a water column temperature profile near the site of the moored buoy indicated that the transmission of bowhead calls was likely to be limited to a greater degree by shallow water propagation loss than by water temperature (Figure 21A). A bowhead call propagating through the shallow water of the study area would be reflected from the surface and the bottom, continually losing energy to scattering and absorption. Depending on the location of the calling whale, bathymetry near the moored buoy would attenuate the call to a greater or lesser degree. A diagram depicting depth at various radial distances from the moored sonobuoy indicates that a whale calling seaward of the 97°T and 240°T radial had a greater likelihood of being detected than those calling between the 120°T and 210°T radial (Figure 21B). Calls produced by whales seaward of the moored sonobuoy traveled through water deeper than that at the hydrophone and

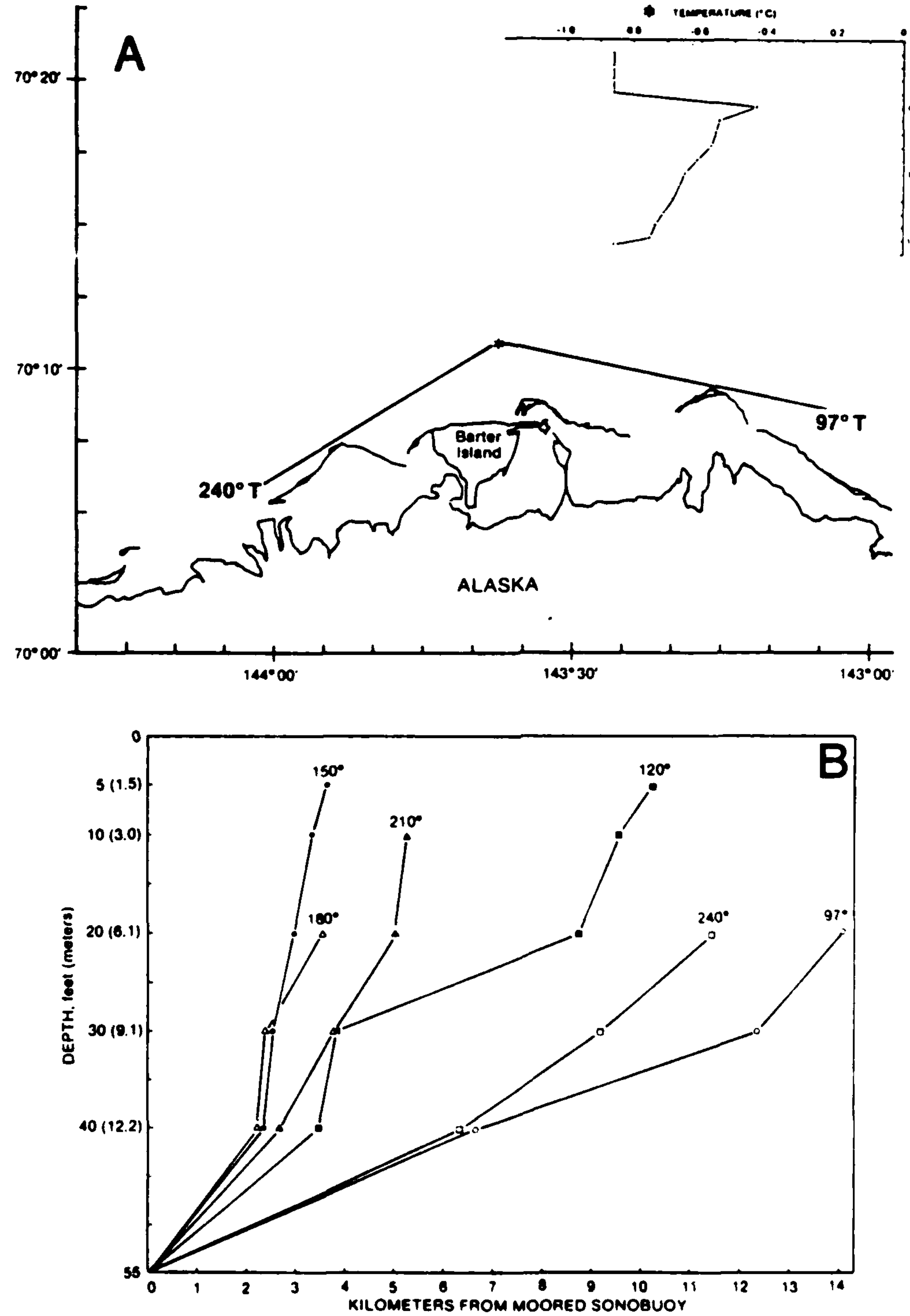


Figure 21. Water column temperature profile (A) and bathymetry (B) near the location of the moored sonobuoy at the Barter Island acoustic station.

were not as affected by bottom and surface attenuation as those produced by whales shoreward of the hydrophone. Calls produced by whales southeast or southwest of the barrier islands (at approximately 143°15'W and 143°55'W respectively) were probably not detected due to acoustic shadowing by these sandbars.

The effect of water column temperature on bowhead call propagation was likely minimal. A temperature profile obtained on 10 October using an expendable bathythermograph depicts water column temperature as nearly linear at -0.86°C from 0.9 to 4 m, followed by a colder-with-depth curve with a temperature "high" of -0.43°C at 5 m to -0.86°C at 15 m (Figure 21A*). The cold water surface lens was probably the result of ice melt. Sounds deflected toward the surface would have been scattered and reflected at this interface, with the overall effect of bringing the "surface" 4 m closer to the bottom as far as sound absorption loss is concerned. This overall effect of water column temperature on sound propagation in the study area was much less than the shallow water shadowing effect described above. Often the entire top 20 m of water is described as a "surface layer" in which sound velocity is subject to daily and local changes due to heating, cooling and, in the Arctic, ice formation or melt (Urick, 1983). Because the buoy was, of necessity, moored in water <20-m deep, these daily changes undoubtedly occurred, but were not restrictive to the study.

After considerations for signal attenuation due to local temperature and bathymetry profiles, spreading loss is the most significant contributor to a description of sound propagation. While attenuation loss varies linearly with range, spreading loss varies according to the logarithm of the range (r) and so can be expressed as a certain number of decibels (dB) per distance doubled. Spreading loss is generally described as spherical (20 log r) when the signal propagation distance is less than hydrophone depth, or cylindrical (10 log r) when the signal travels a distance greater than hydrophone depth (Urick, 1983). Thus, a model of sound transmission through the study area based upon cylindrical spreading is appropriate based on the imposed shallow water hydrophone deployment previously described. The source level of bowhead calls has been estimated at 189 to 200 dB, with a median estimate of 193 dB. Using this median source level and the hybrid spreading loss model, a bowhead calling 10 km from the hydrophone should generate a 133-dB signal, while a whale at 20 km should produce a 128-dB signal at the hydrophone. These levels, before allowing for attenuation, are well above the

65- to 70-dB average ambient noise level previously reported for the shallow Beaufort Sea (Buck, 1981; Moore et al., 1984). If we assume that the signal-to-noise ratio falls to zero at 20 km, an attenuation factor of 5.5 dB/km may be derived allowing bowhead call propagation in the study area to be generalized as:

Bowhead call	-	Spreading loss	-	Attenuation loss	=	call signal/ambient noise
193 dB	-	10 log (20 km)	-	5.5 dB/km		68 dB/68 dB = Ø

Number and Type of Bowhead Calls Recorded

A total of 7,152 bowhead calls were recorded over the course of the season. The types of calls recorded were similar to those previously described (Ljungblad, Thompson and Moore, 1982; Clark and Johnson, 1984). Most calls were the tonal frequency-modulated (FM) type that are often described as "moans," although amplitude-modulated (AM) "growl" and "trumpet" calls were also recorded.

Three phases of calling activity stood out over the course of the season (Table 27; Figure 22): an initial period of very low call rates (CR = 0.09 to 0.23) that began on 3 September and ended on 12 September; a second period that extended from 18 to 20 September when call rates ranged from 1.39 to 7.26; and a third period of very active calling (CR = 0.30 to 88.24) that began on 25 September and ended on 9 October. The first period of low calling rates corresponds with the onset of the bowhead migration on 10 September, as recognized by the U.S. National Marine Fisheries Service (NMFS). The NMFS declared 10 September as the "start" of the migration based on visual sighting data, however, as only three bowhead calls had been recorded prior to that date.

The majority of calls (n = 6664, 93%) were recorded during the third period of calling activity. There were two peaks in the number of calls per day and call rate (CR = number calls/hours of recording) between 27 September and 3 October. The first and largest peak occurred on 28 September when 2100 calls were recorded at a rate of 88.24 calls per hour. On the days immediately before and after this peak 661 and 534 calls were received, resulting in a call rate of 28.61 and 24.61 calls per hour respectively. On 30 September, only 55 calls were recorded (CR = 7.43), seeming to mark the end of this first peak of acoustic activity. The second peak in calls occurred on 1 October (n = 1566 calls; CR = 70.22), with call rate remaining relatively high through 2 October (n = 1373 calls; CR = 62.69) and dropping to a

Table 27. Hours of recording, number of bowhead calls, and call rate (no. calls/hour) recorded at the Barter Island acoustic station, 25 August to 11 October, 1986.

Date	Hours	No. Calls	Call Rate	Date	Hours	No. Calls	Call Rate
25 Aug	6.9	0	0	18 Sep	23.0	32	1.39
26 Aug	5.8	0	0	19 Sep	14.6	106	7.26
27 Aug	6.4	0	0	20 Sep	23.9	119	5.00
28 Aug	13.3	0	0	21 Sep	0.7	0	0
29 Aug	0	-	-	22 Sep	13.7	0	0
30 Aug	3.0	0	0	23 Sep	11.7	0	0
31 Aug	0	-	-	24 Sep	0	-	-
1 Sep	0	-	-	25 Sep	8.2	52	6.34
2 Sep	0	-	-	26 Sep	22.3	0	0
3 Sep	10.3	1	0.10	27 Sep	23.1	661	28.61
4 Sep	24.0	0	0	28 Sep	23.8	2100	88.24
5 Sep	23.6	0	0	29 Sep	21.7	534	24.61
6 Sep	17.7	0	0	30 Sep	7.4	55	7.43
7 Sep	17.2	0	0	1 Oct	22.3	1566	70.22
8 Sep	12.9	0	0	2 Oct	21.9	1373	62.69
9 Sep	23.4	2	0.09	3 Oct	23.2	375	16.16
10 Sep	18.6	0	0	4 Oct	11.3	0	0
11 Sep	10.0	1	0.10	5 Oct	0	-	-
12 Sep	8.6	2	0.23	6 Oct	9.4	136	14.47
13 Sep	8.4	0	0	7 Oct	22.1	35	1.58
14 Sep	5.3	0	0	8 Oct	0.4	0	0
15 Sep	13.5	0	0	9 Oct	6.6	2	0.30
16 Sep	16.5	0	0	10 Oct	12.4	0	0
17 Sep	11.7	0	0	11 Oct	9.6	0	0
				TOTAL	**590.4**	**7152**	**12.11**

rate of 16.16 calls per hour by 3 October. There were no calls heard on tapes reviewed in the field on 4 October, and no recordings made on 5 October due to bad weather that prohibited the replacement of a buoy. A third small peak in call rate was detected on 6 October (CR = 14.47), with a drop to CR = 1.58 by 7 October. Weather conditions again prevented the replacement of a buoy on 8 October, and by 9 October call rate had dropped to 0.30 calls per hour.

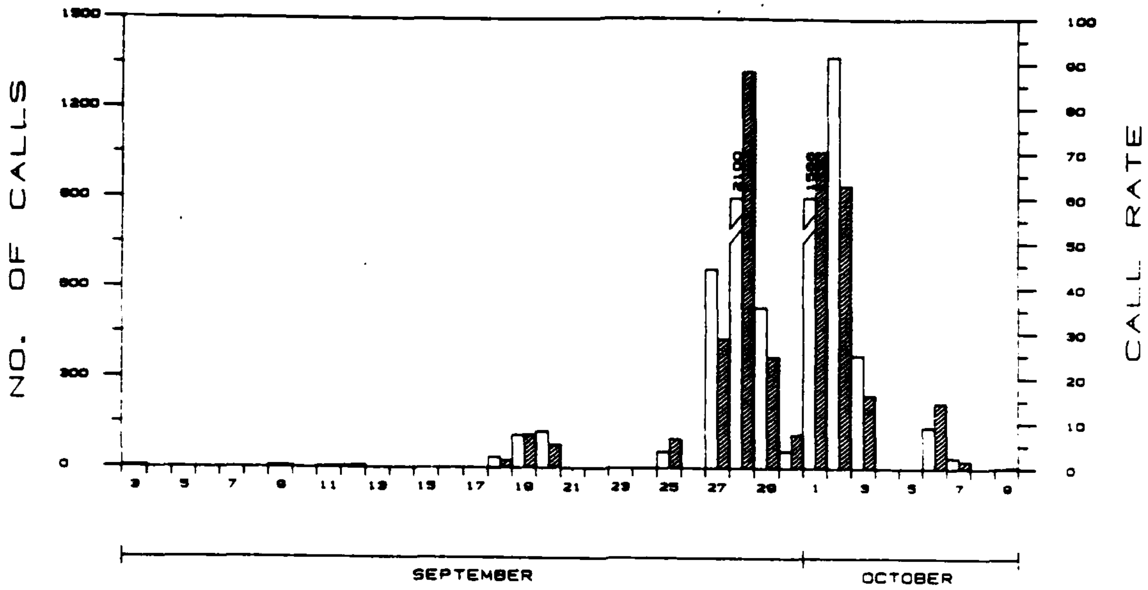


Figure 22. Histogram depicting number of bowhead calls and call rate (calls/hour) at the Barter Island acoustic station.

There was no significant indication of a diurnal pattern to call production when nighttime and daytime hourly call rates for the two peak recording days (28 Sep and 1 Oct) were compared. On 28 September, there was a weak trend supporting higher average call rates from 1800 to 0600 ($\bar{x}$ = 101 calls/hr) than from 0600 to 1800 ($\bar{x}$ = 74 calls/hr; $p < 0.20$). There was no such trend evident in the data from 1 October, nor when the call samples from both days were combined.

Association of Bowhead Call Rates With Aerial Survey Sighting Rates

Three aircraft and crews conducted aerial surveys for bowhead whales in the vicinity of the acoustic station during September and early October (Table 28). There were no bowheads seen within the range of the acoustic station on 3 or 9 September when the first three calls were recorded. The closest whales on those dates were over 71 km and 66 km away respectively. On 11 September, one whale was seen within (potential) range of the sonobuoy and 9 whales were seen just beyond the presumed reception range of the hydrophone (Table 28, Figure 23). Bowheads were not routinely seen near the acoustic station until 25 September. Between 25 September and 6 October, 15 bowheads were sighted within 20 km of the hydrophone, with an additional 7 whales seen from 20 to 26 km away (Table 28). The greatest number of bowhead sightings (n = 11) near the acoustic station occurred during the latter half of September, while whales were seen closest to the

Table 28. Correlation of bowhead sightings from three survey aircraft (A/C), their associated SPUE, WPUE and whale-to-sonobuoy distance, with daily bowhead call rate (CR) recorded at the acoustic monitoring station.

DATE	A/C	SI/NO	DIST (km)	*SPUE (<20 km)	*WPUE (<20 km)	CR
11 Sep	LGL-FS	1/1	19.91	0.14	0.14	0.10
	LGL-C/H	1/9	24.58			
25 Sep	LGL-C/H	1/1	24.11	0.52	0.52	0
25 Sep	302EH	3/3	22.26			
			23.11			
			9.85			
26 Sep	LGL-FS	3/4	23.51	0	0	0
			24.05			
			25.84			
28 Sep	302EH	4/7	15.72	5.26	9.21	88.09
			19.47			
			11.16			
			17.65			
2 Oct	LGL-C/H	1/4	7.92	1.92	7.68	62.78
6 Oct	302EH	3/3	3.61	11.11	11.11	14.48
			6.25			
			5.10			

*SPUE and WPUE were estimated for LGL aircraft based upon survey track lines and a survey speed of 203.5 km/hr. All abundance estimates represent only whales seen <20 km from sonobuoy.

LGL-FS = LGL-feeding study; LGL-C/H = LGL-Corona/Hammerhead

moored sonobuoy ($\leq$8 km) during the first part of October (Figure 23). There were no bowheads seen in the vicinity of Barter Island after 11 October when the acoustic study was terminated, although flight effort was also ended by 15 October.

Estimates of bowhead relative abundance (SPUE and WPUE) were calculated for whales seen within 20 km of the moored sonobuoy in the acoustic study area (Table 28) and compared to daily call rate (CR) via regression analysis. Although there were no significant correlations of CR with WPUE or SPUE, there was a trend for high WPUE to be associated with increased call rate ($r = 0.665$, $p < 0.20$). This association indicates that calling bowheads migrating west within 25 km of Barter Island (i.e., within 20 km of the hydrophone set 5 km north of the island) were well represented by the call rate derived for that day. Further, the peak day

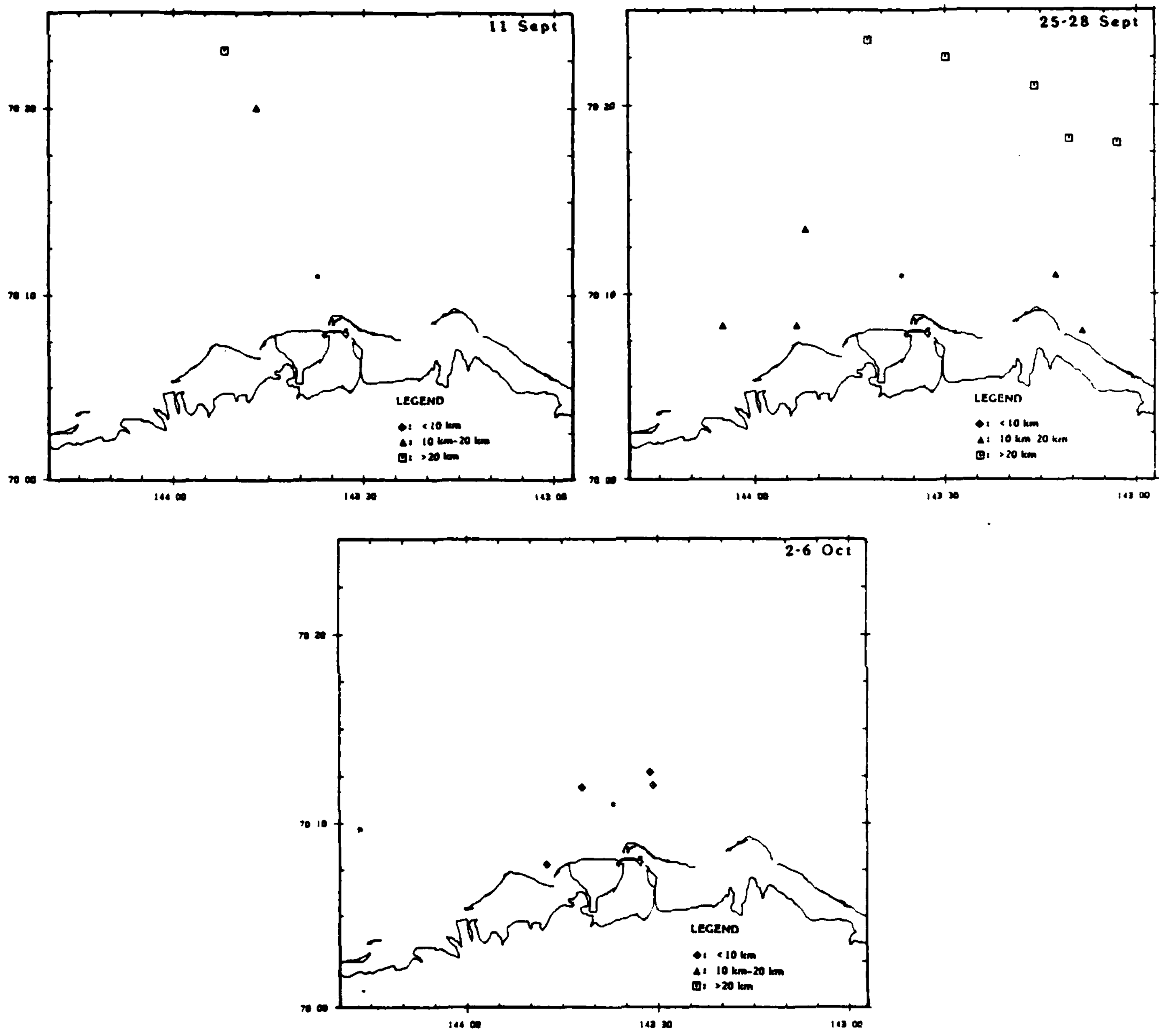


Figure 23. Depiction of bowhead sightings in relation to the acoustic monitoring station (*), 1986.

for call rate (28 September) corresponded with high abundance indices for the acoustic study area for whales < 20 km from the hydrophone, as well as with the peak abundance indice for the overall season (Figure 14).

These preliminary results are encouraging because they suggest that acoustic monitoring may be a cost effective way to monitor and assess the migratory timing of bowheads passing through the nearshore regions of the Beaufort Sea. The fall bowhead migration is sometimes composed of two intergrading components; an early offshore component that moves northwest in August (e.g. 1979 and 1982), and a later nearshore component that migrates along Alaska's North Slope during the latter half of September and through October. A semimonthly analysis of bowhead swimming direction for 1979-86 indicates that significant westerly swimming (280°T, $p \leq 0.001$) of nearshore whales does not begin until the second half of September (see Figure 37). Whales seen in early August maintain significant northwesterly headings (309°T, $p < 0.01$), but these whales are seen farther offshore and in deeper water than whales seen in September and October (see Figure 31). Passive acoustic monitoring provides a means of detecting the September-October nearshore migrants through periods of darkness and bad weather provided conditions are conducive to maintaining the necessary field equipment. The 1986 field season was unusually mild, with ample periods between storms that allowed the moored sonobuoy systems to be replaced at timely intervals. A season of prolonged storms, such as 1985, or heavy ice (i.e. 1980 and 1983) would have likely led to fewer acoustic results.

Other Marine Mammals Recorded

a. Belukha

Belukha calls were recorded at the acoustic monitoring station on 3, 16, and 17 and 28 September (Table 26). The only day they were seen in the study area was 28 September (Appendix A, 302EH: Flight 15). Belukhas make a variety of relatively high frequency calls (300 Hz to 20 kHz) that have been described as whistles, yelps, blares, rasps, bangs, peeps, trills and squawks (Fish and Mowbray, 1962; Ford, 1975). Such high-frequency calls were probably attenuated over shorter distances in the shallow water study area than were the lower frequency bowhead calls (Urick, 1983). This rapid attenuation of high frequencies, combined with the overall offshore distribution of belukhas during the fall season (see Figure 39), may account for the few number of days they were recorded.

b. Bearded Seal

Bearded seal calls were recorded at the acoustic monitoring station intermittently from 3 September through 7 October (Table 26). Three "barks" were recorded on 27 August that may have been produced by a bearded seal or a ringed seal. A notation of the distinctive trill-type call was made, but the number of trill-call events were counted on only one tape (n = 47 trills, 26 September). Bearded seals were seen in the study area only once on 31 August (Appendix A, N780: Flight 12). In a paper describing the use of arctic pinniped vocalizations as a tool for studying their distribution and relative abundance, Stirling et al. (1983) notes that bearded seal calls may be recorded up to 45 km from their source under ideal conditions. This may account for the relatively high incidence of recording these pinnipeds.

Ambient Noise

Ambient noise is background noise that does not have an identifiable source (Urick, 1983). Ambient noise sources include tides and waves, naturally occurring seismic activity, oceanic turbulence, thermal noise, distant ship traffic, and distant biological noise. In coastal waters, wind speed and its resultant sea state have been cited as the strongest factor in determining overall noise level between 10 Hz and 3 kHz (Urick, 1983). This relationship between wind speed and coastal water ambient noise level has been documented both in open water and in partial ice-cover conditions (Milne et al., 1967). Sea state during the acoustic monitoring study varied from a Beaufort 00-01 during calm periods to 06-08 during storms. A spectrum of the 15- to 500-Hz band indicates that ambient sea noise increased by about 12 dB during storms (Figure 24). Ambient noise during calm periods averaged 65 dB in the 15- to 200-Hz band and 60 dB between 200- and 500-Hz. During storms ambient noise was approximately 77 dB from 15 to 100 Hz and about 72 dB in the 100- to 500-Hz band.

Although sea state is generally considered the strongest factor determining ambient noise levels in coastal waters, sounds thought to be produced by melting or drifting ice are sometimes aurally distinct on tape. Crackling and scraping sounds often dominated recordings made at the acoustic station when local ice conditions were heavy. A spectrum of ambient noise during heavy-ice and ice-free conditions indicates that, although sea ice may not be a significant contributor to overall ambient noise in the 15- to 500-Hz band (Milne et al., 1967; Moore et al., 1984), it can result in short periods of relatively higher noise levels. Ambient noise levels in

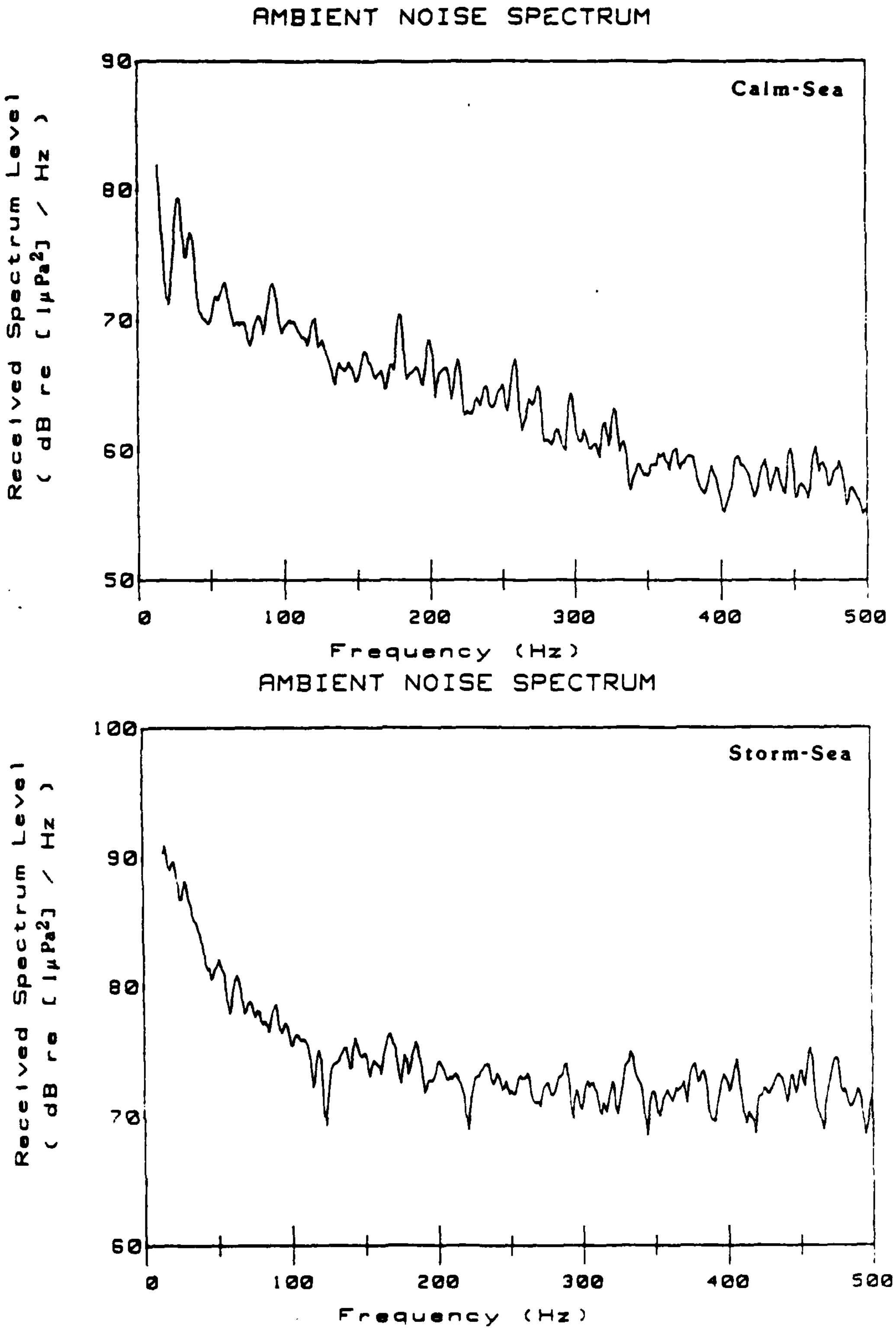


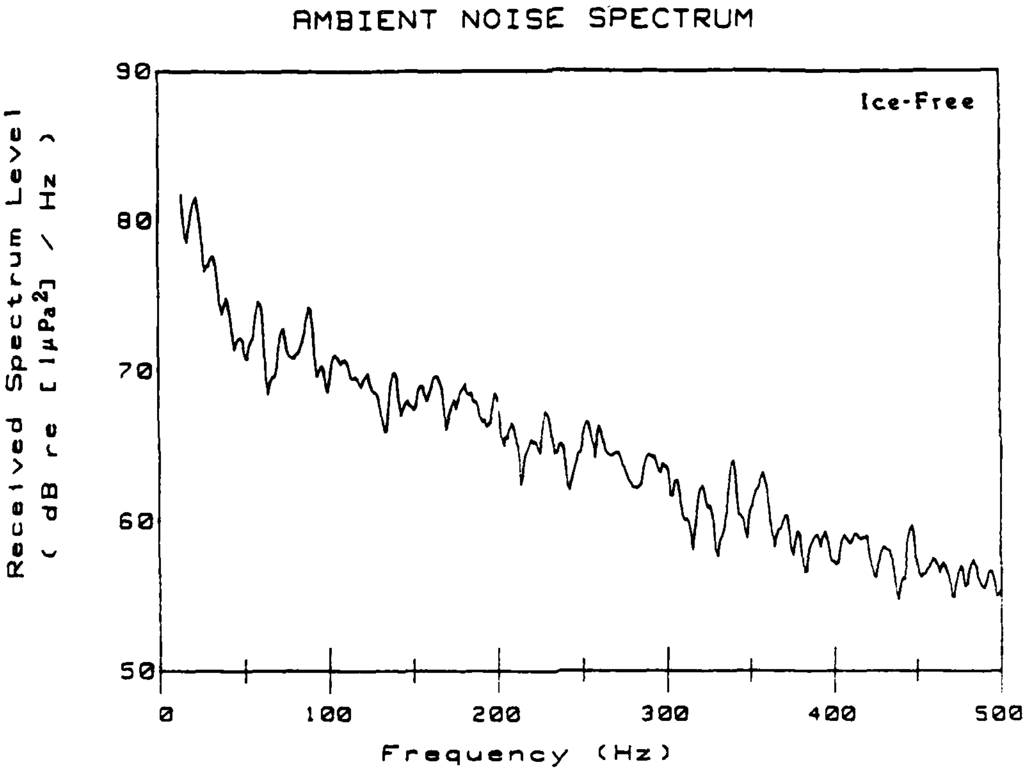
Figure 24. Ambient noise spectrum for data recorded at the acoustic monitoring station during calm-sea and storm-sea recording conditions.

the 15- to 500-Hz band averaged 62 dB during calm ice-free periods, and rose to about 74 dB during heavy-ice conditions, with components attributable to ice scrapping near 180 Hz, 300 Hz, and 400 Hz (Figure 25). Potentially, heavy-ice and/or storm ambient-noise levels could mask bowhead calls resulting in lower counts during those periods.

Industrial Noise

Industrial noise sources recorded over the course of the acoustic monitoring study included outboard motors, geophysical vessel engine noise and airgun blasts. Outboard engine noise, from our skiff and small boats used by local residents for fishing and whaling, was the most common noise source in the study area. A spectrum of noise generated by the 20-hp Mercury outboard used on our skiff at 9 to 10 m from the hydrophone averaged 80 dB across the 15- to 500-Hz band with tonal components at 150 Hz and 300 Hz (Figure 26). The overall spectrum was one of numerous peaks probably due to cavitation noise caused by the propeller. The frequency and decibel level of outboard engine noise will vary with engine type, boat speed, and aspect. This single spectrum serves only as a single-capture example of the type of noise generated by outboard engines.

Engine and airgun blasts generated from a geophysical vessel were also frequent contributors to the underwater acoustic environment at the acoustic station. An example spectrum of engine noise and airgun blasts indicate that received noise from these sources, when the vessel was approximately 40 to 42 km away, were generally no louder than that from close passing outboards (Figure 27). Engine noise recorded from the geophysical vessel on a day of extremely quiet ambient conditions was 40 dB in the 15- to 500-Hz band, with propeller blade-rate harmonics that had a fundamental at about 60 Hz and peaks to 78 dB. A spectrum of an airgun blast depicts strongly elevated levels centered at about 100 Hz, with a fall off in level above 200 Hz. The noise from geophysical vessel engines and airguns has been further documented and described elsewhere (Greene, 1985; Moore et al., 1984, Ljungblad et al., 1985b: Appendix A).



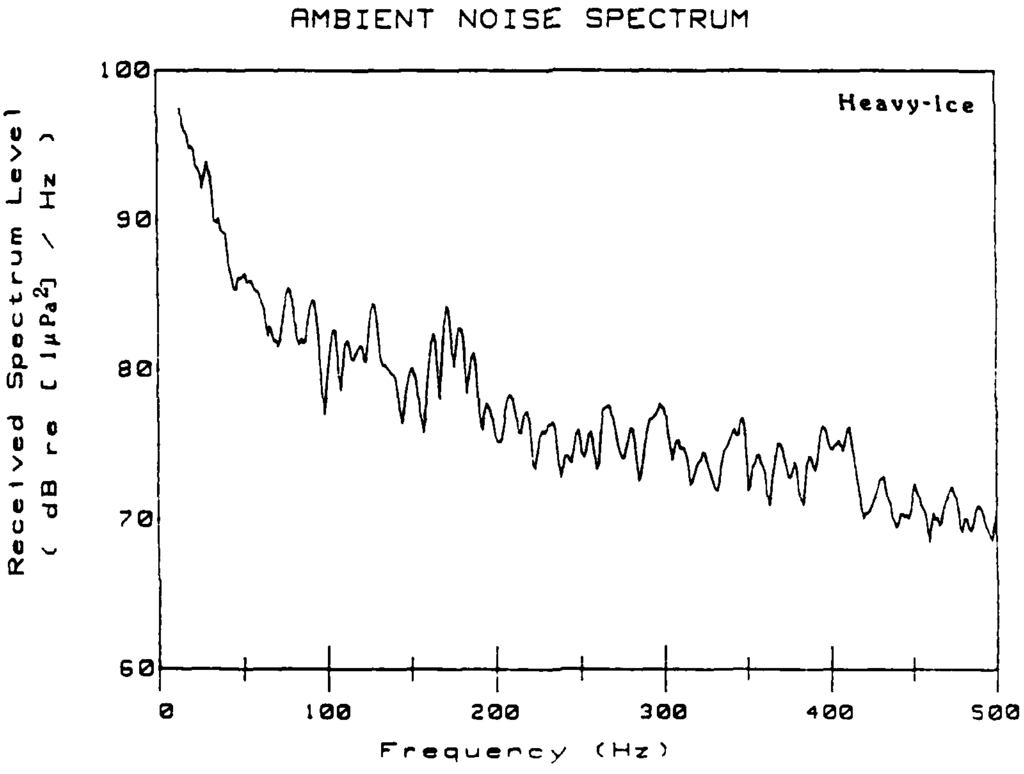


Figure 25. Ambient noise spectrum for data recorded at the acoustic monitoring station during heavy-ice and ice-free recording conditions.

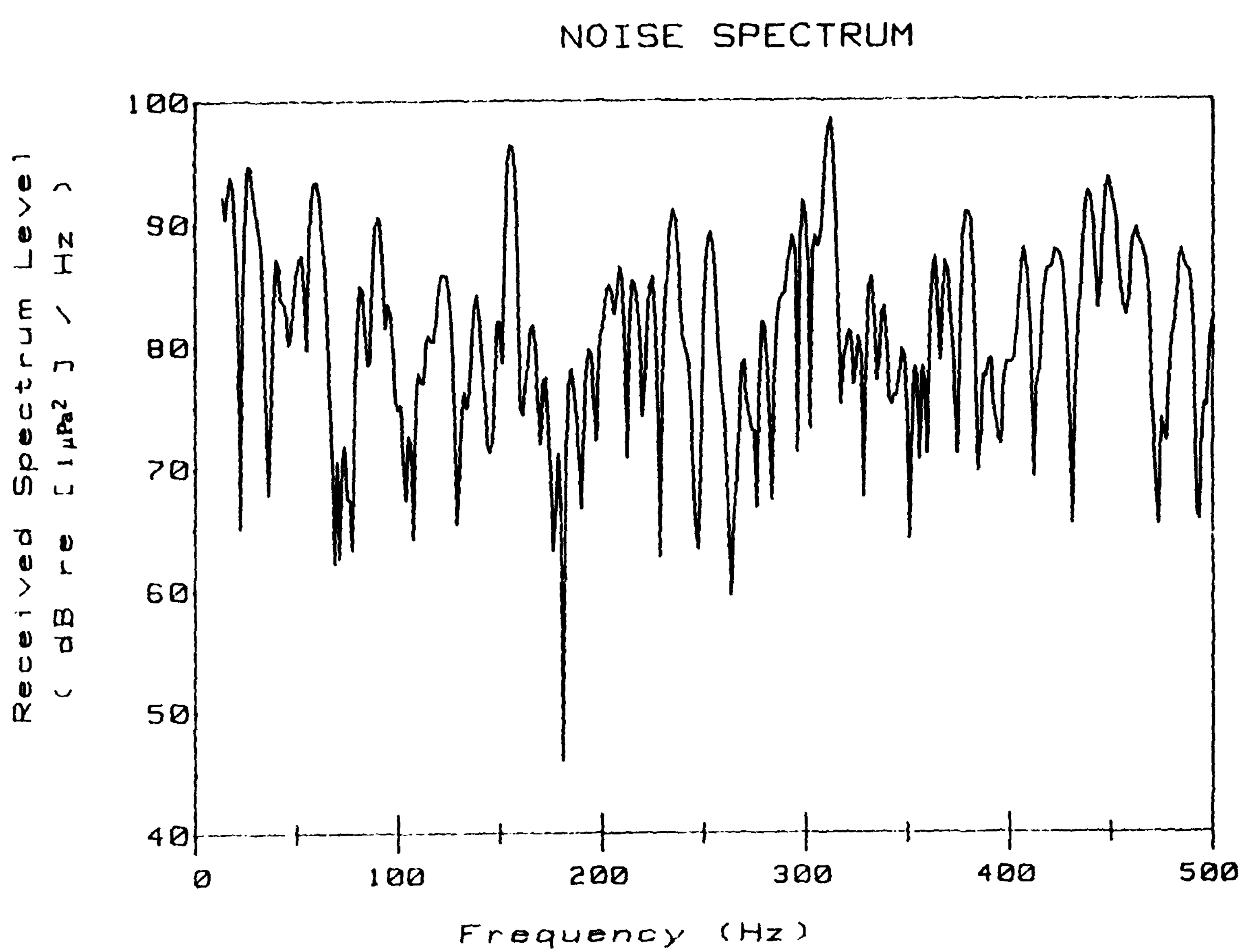


Figure 26. Noise spectrum from an outboard engine recorded as it passed the acoustic monitoring station.

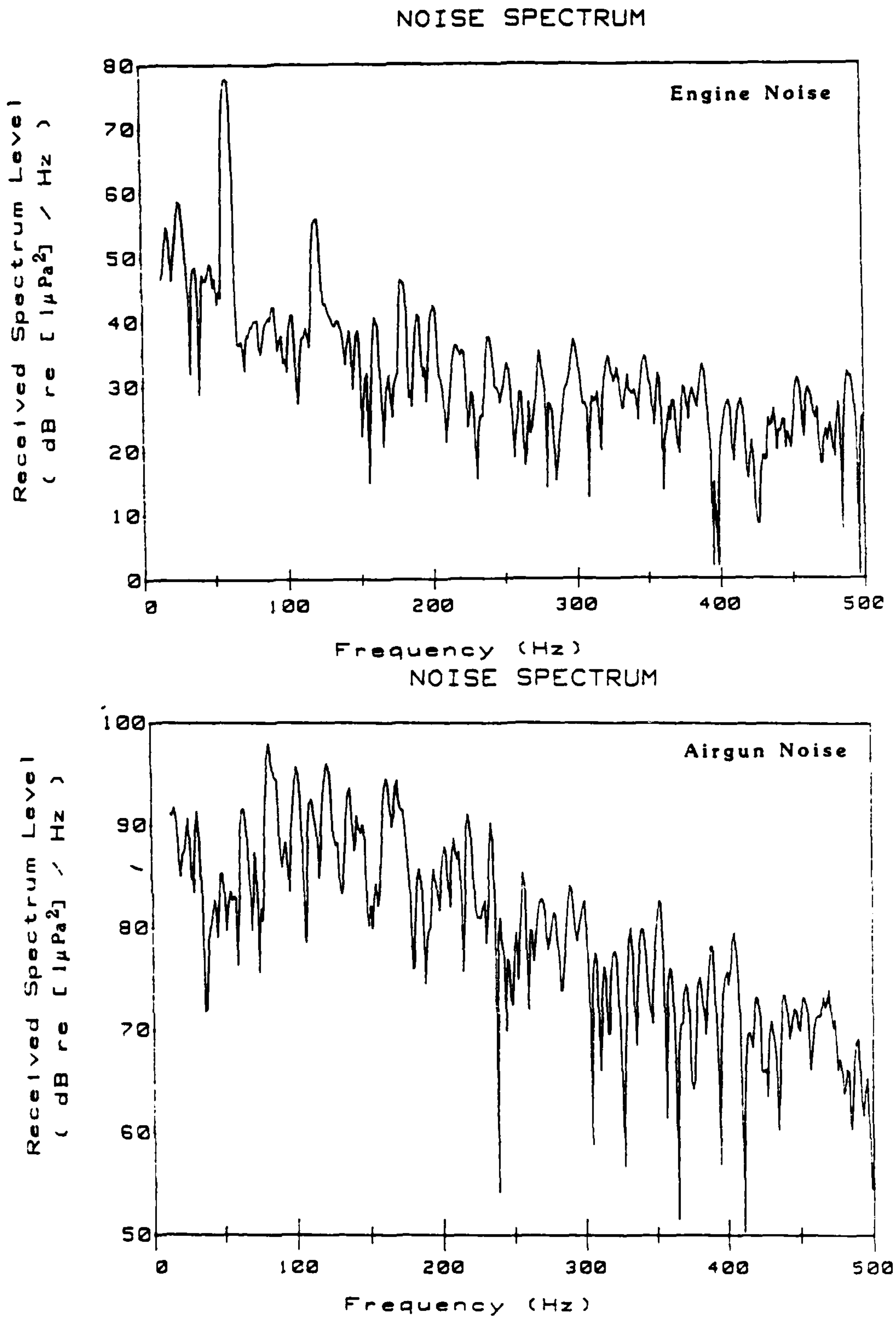


Figure 27. Spectrums of engine and airgun noises from a geophysical vessel working in the vicinity of the acoustic monitoring station.

DISCUSSION AND 1979-86 REVIEW

This section represents a review and synthesis of data gathered on aerial surveys of endangered whales conducted from 1979 to 1986. Results of these surveys have appeared in annual reports for the Minerals Management Service finalized as NOSC technical documents or technical reports (Ljungblad, 1981; Ljungblad et al., 1980, 1982a, 1983, 1984a, 1985a, 1986b) as well as in summary manuscripts presented in other articles/forums (e.g. Clarke et al., 1987; Ljungblad et al., 1986a, 1986c; Moore et al., 1986a, 1986b).

The objectives and methods of data collection and analyses on the primary aircraft (N780) have remained similar throughout all years with few exceptions. Since 1982, a microcomputer has been used aboard the aircraft to record and later analyze data. In 1986, in addition to the primary survey aircraft, a second aircraft flew transect surveys, and an acoustic station was set up to monitor the nearshore bowhead migration. Data resulting from these efforts have been incorporated into the larger data base. Bowhead and gray whales have been the principal species studied over the years due to their endangered status and have been the only species addressed in past Conclusions and Review sections. However, this year all species seen during fall aerial surveys are included. This was the first year since 1980 that surveys were not flown in summer (July). A review of 6 years of summer survey efforts and results was presented in Ljungblad et al. (1986b). A review of spring (April, May) survey results was presented in Ljungblad et al. (1985a).

This review follows a species format, and covers the same areas of interest as the main body of the seasonal report. The objectives of the surveys and a brief overview of survey effort and conditions are presented prior to presentation of species accounts.

Aerial Survey Objectives, Effort and Conditions Summary

The primary objectives of the fall aerial surveys have been to determine the distribution and timing of the bowhead whale migration, to derive relative and absolute abundance estimates in or near proposed or existing federal lease areas, and to describe bowhead whale general behavior and record underwater sound production. In 1986, the primary objectives also included documenting the distribution, relative and absolute abundance estimates, and general behavior of gray whales in the northeastern Chukchi Sea. Secondary objectives were to document distribution of other marine mammal species encountered during surveys.

Table 29. Summary of flight effort (hours:minutes) by sea, fall 1979-86.

	1979	1980	1981	1982	1983	1984	1985	1986	Total (%)
Bering Sea	0	33:45	14:43	0	0:42	0	0	0	49:10(3)
Chukchi Sea	0:48	14:30	11:24	18:56	42:41	31:19	15:06	83:41	218:25(12)
Beaufort Sea	171:06	156:49	144:19	204:44	236:29	214:47	197:43	203:15	1529:12(85)
TOTAL	171:54	205:04*	170:26	223:40	279:52	246:06	212:49	286:56	1796:47

*includes 21:38 flown in November 1980

A total of 1796.7 survey hours has been flown in the fall since 1979, with 85 percent (1529.1 hours) of this effort in the Beaufort Sea, 12 percent (218.4 hours) in the Chukchi Sea, and 3 percent (49.2 hours) in the Bering Sea (Table 29). There has been considerable variability in survey effort over the years. There was little effort flown in August 1979-81, due to aircraft availability and/or its occasional diversion to support other MMS-funded projects, and in 1986 when surveys were flown only in the latter half of August. Areas covered in September and October have varied from year to year depending on the emphasis and goals of the project (Ljungblad et al., 1986b). In 1986, unlike any other year, widespread coverage was given to the Alaskan Beaufort and Chukchi Seas due to the presence of two full time survey aircraft from early September through mid-October. The termination of fall survey effort in the Beaufort and Chukchi Seas has occurred between 14 to 31 October, although in 1980 surveys were continued in the Bering Sea in early November.

Fall-ice conditions varied annually, but most years can be categorized as having either predominantly heavy (70 to 90%) or light (0 to 30%) cover. In heavy-ice years (1980, 1983), ice cover remained heavy throughout the fall season. In light-ice years (1979, 1981, 1982, 1984, 1986) ice cover in the Alaskan Beaufort was relatively heavy through August, became and remained light through September, with freeze up commencing in early to mid-October. Ice conditions in 1986 were extremely light, with the ice edge remaining farther offshore than normal and freeze up occurring later in October than usual. Ice conditions in 1985 were intermediate to other years, as average ice cover varied between 30 and 70 percent for most of August and September.

Sea states encountered on fall surveys ranged from Beaufort 00 to 06, with Beaufort 01 to 03 conditions the most common. Sea states during heavy-ice years generally ranged from Beaufort 00 to 02 due to the dampening influence of the ice cover. Fog often caused surveys to be truncated or aborted in August and September when ice conditions changed daily. In October, high winds curtailed survey efforts.

Bowhead Whale

Patterns of Distribution, Relative Abundance, and Density

There were 1064 sightings of 1870 bowheads made over eight fall seasons (Table 30, Figure 28). The distribution of 158 bowheads seen in 1986 (Figure 9) was similar to, but not comprehensive of, past years.

In August, bowheads have been seen 0.5 to 180 km from shore between 138°W to 147°W, with annual variation as follows:

- In 1979, 7 whales were seen between 143°W and 144°30'W, offshore to 70°41'N
- In 1981, 2 whales were seen near 138°W, at 69°33'N
- In 1982, 145 whales were seen between 139°33'W and 145°49'W, offshore to 71°54'N
- In 1983, 59 whales were seen between 139°38'W and 146°48'W, offshore to 71°03'N
- In 1984, 21 whales were seen between 139°W and 141°26'W, offshore to 70°23'N
- In 1985, 12 whales were seen from 140°W to 141°56'W, offshore to 70°31'N
- In 1986, 41 whales were seen between 139°22'W and 144°35'W, offshore to 70°29'N

There was little survey effort in August 1979-81 in the Beaufort Sea, and bowhead distribution and numbers were probably underrepresented for those years. In 1986, there was no survey effort in the first half of August; therefore, distribution and numbers may be underrepresented for 1986 as well. Since 1982, August surveys have been routinely flown in blocks 1 through 9, and bowheads were seen in all blocks except 1, 3, 4, and 8. Many more whales were seen, and their distribution extended farther north and west, in 1982-83 than in 1984-86. Much of

Table 30. Semimonthly summary of bowhead sightings (number of sightings/number of whales), 1979-86.

YEAR	AUGUST		SEPTEMBER		OCTOBER		TOTAL
	1-15	16-31	1-15	16-30	1-15	16-31	
1979	(0)	(4/7)	2/2	28/58	60/86	27/44	121/197
1980	(0)	(0)	9/12	15/22	8/12	(0)	32/46
1981	(0)	(1/2)	47/63	144/169	43/54	--	235/288
1982	57/108	22/37	25/54	90/247	27/43	(1/1)	222/490
1983	25/49	7/10	19/24	41/54	17/24	(7/11)	116/172
1984	2/3	11/18	12/17	64/243	52/77	(13/22)	154/380
1985	8/9	3/3	13/34	18/33	34/59	(1/1)	77/139
1986	(6/12)	15/29	23/40	34/39	27/35	(2/3)	107/158
TOTAL	(98/181)	(63/106)	150/246	434/865	268/390	(51/82)	1064/1870

( ) = surveys not conducted over entire period
-- = no surveys conducted

the August offshore distribution of bowheads in 1982-83 was seen during the first half of the month. Since surveys were not flown from 1 to 14 August 1986, it is possible that bowheads were present in the offshore eastern Alaskan Beaufort at that time. This is not highly probable, however, since bowheads were not seen in any appreciable numbers offshore in the latter half of the month. The 1986 August bowhead distribution was similar to 1984-85 (Ljungblad et al., 1986b). In all years since 1982, August bowhead distribution has coincided with only the easternmost boundaries of OCS oil and gas lease areas; generally, whales have been seen north, east, or shoreward of lease areas (Figure 28).

In September, bowheads have been seen across the Alaskan Beaufort Sea generally along the shelf break and into the northeastern Chukchi Sea, with annual variation as follows:

- In 1979, 60 whales were seen between 140°58'W and 146°33'W, offshore to 70°38'N
- In 1980, 34 whales were seen between 138°45'W and 149°43'W, offshore to 70°53'N

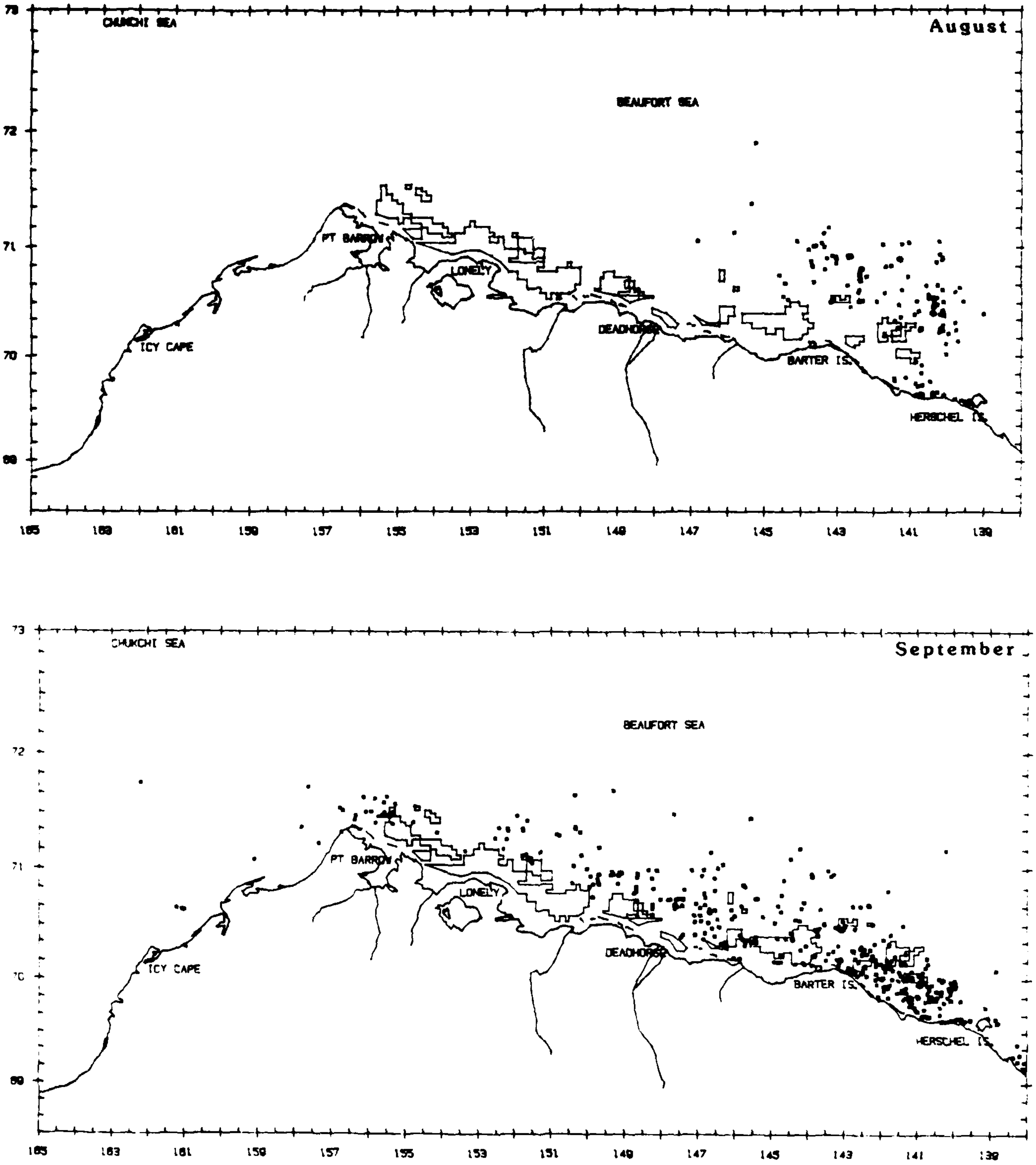


Figure 28. Distribution of 1064 sightings of 1870 bowheads, 1979-86: 161 sightings of 287 whales, August; 584 sightings of 1111 whales, September;

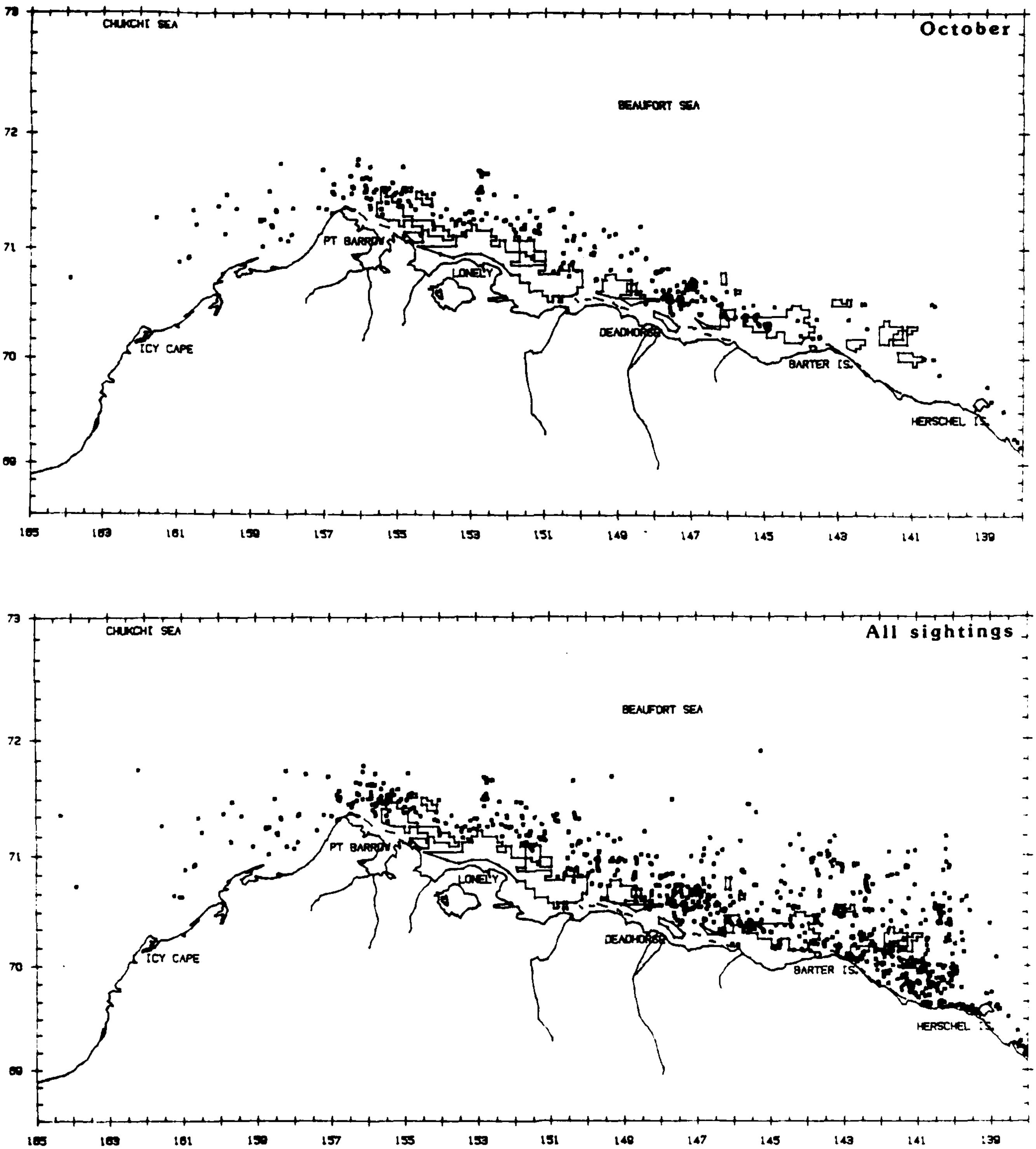


Figure 28 (contd). 319 sightings of 472 whales, October; all sightings. Outlined areas depict OCS oil and gas lease areas within the Beaufort Sea Planning Area in the Alaskan Beaufort Sea.

- In 1981, 232 whales were seen between 138°16'W and 146°27'W, offshore to 70°23'N
- In 1982, 301 whales were seen between 139°47'W and 155°37'W, offshore to 71°39'N
- In 1983, 78 whales were seen between 140°12'W and 161°14'W, offshore to 71°41'N
- In 1984, 260 whales were seen between 137°58'W and 157°39'W, offshore to 71°43'N
- In 1985, 67 whales were seen between 139°01'W and 146°41'W, offshore to 70°40'N
- In 1986, 79 whales were seen between 138°47'W and 162°12'W, offshore to 71°45'N

The 1979-81 September survey effort was directed mainly to blocks 1 through 6, and whales were seen in all blocks except 2 and 3. In 1982-85, September surveys were routinely flown in blocks 1 through 13, with only occasional coverage in blocks 14 and 17. In September 1986, when transect surveys were flown by two aircraft, both the Chukchi (blocks 13 to 18 and 20) and the Alaskan Beaufort (blocks 1 to 8, 11 and 12) Seas were covered. September bowhead distribution has included blocks 1 through 13, except in 1985 and 1986. The 1985 distribution was similar to nearshore distributions seen in 1979-81, when surveys were confined to near-shore blocks. The September 1986 distribution was unlike any other year, as all but two bowheads were seen east of 147°W. This distribution may be an artifact of reduced flight effort in the western Alaskan Beaufort Sea blocks (1, 2, 3, 11, and 12), or may have been due to a protracted migration initiated later than in other years. In all years, September bowhead distribution has overlapped the boundaries of OCS oil and gas lease areas between 141°W and 147°W, been generally north of the lease areas between 147°W and 155°W, and overlapped the northwesternmost OCS lease areas (Figure 28).

In October, whales have been found along the shelf break in the Beaufort Sea, with relatively more whales seen west of 150°W and in the northeastern Chukchi Sea than in September (Figure 28). Annual variation in October bowhead distribution was as follows:

- In 1979, 130 whales were seen between 144°45'W and 155°40'W, offshore to 71°32'N

- In 1980, 12 whales were seen between 144°02'W and 153°10'W, offshore to 71°18'N
- In 1981, 54 whales were seen between 143°36'W and 153°24'W, offshore to 71°16'N
- In 1982, 44 whales were seen between 138°52'W and 160°34'W, offshore to 71°45'N
- In 1983, 35 whales were seen between 140°24'W and 163°54'W, offshore to 71°44'N
- In 1984, 99 whales were seen between 137°51'W and 159°42'W, offshore to 71°48'N
- In 1985, 60 whales were seen between 147°21'W and 160°29'W, offshore to 71°43'N
- In 1986, 38 whales were seen between 143°30'W and 161°34'W, offshore to 71°38'N

Survey efforts in October covered near-shore and offshore Beaufort Sea and coastal Chukchi Sea survey blocks (i.e., generally blocks 7 to 18) after 1981. In 1986, survey effort was limited to near-shore Beaufort Sea blocks west of 143°W (blocks 1 to 4, 6, 11, 12), with widespread coverage of the northwestern Chukchi Sea (blocks 13 to 15, 17, 18). Bowheads have been seen in October in all Beaufort survey blocks except 8, 9, and 10; in the Chukchi Sea, whales were seen in blocks 13, 14, 17, and 18. October bowhead distribution in 1986 was similar to, but not comprehensive of, past years. More survey effort was completed in the Chukchi Sea in October 1986 (37.63 h) than in any past year, yet few (n = 3) bowheads were seen there. October bowhead distribution overlapped OCS lease area boundaries east of 150°W and west of 154°W in most years (Figure 28).

Bowhead relative abundance (WPUE) was calculated for survey blocks in which bowheads have been seen (Table 31). The annual variation of WPUE reflects the patterns of survey effort and bowhead distribution discussed above. Highest seasonal WPUE was calculated for block 5 in all years, except 1984 and 1985. In 1984, highest WPUE was calculated for block 12 where large aggregations of whales were seen feeding that year (Ljungblad et al., 1986a). Highest WPUE in 1985 was also associated with a group of feeding bowheads in block 11. An annual review of the shifts in highest monthly WPUE may be summarized as follows:

- In 1979, bowhead relative abundance was highest in block 6 in August, block 5 in September, and block 3 in October

Table 31. Bowhead relative abundance (WPUE = no. whales/hours of survey effort) by block, 1979-86.

1979

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	19.25	0	-	24.33	2	0.08	55.76	88	1.58	99.34	90	0.91
2	2.15	0	-	2.50	0	-	3.17	0	-	7.82	0	-
3	0.00	0	-	0.65	0	-	**7.36**	**27**	**3.67**	8.01	27	3.37
4	11.63	0	-	11.39	1	0.09	4.25	10	2.35	27.27	11	0.40
5	0.00	0	-	**5.26**	**53**	**10.08**	0.00	0	-	**5.26**	**53**	**10.08**
6	**5.13**	**7**	**1.36**	5.47	4	0.73	1.02	0	-	11.62	11	0.95
7	0.00	0	-	1.36	0	-	0.00	0	-	1.36	0	-
8	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
9	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
10	0.36	0	-	0.00	0	-	0.00	0	-	0.36	0	-
11	0.00	0	-	0.00	0	-	1.29	0	-	1.29	0	-
12	0.00	0	-	0.42	0	-	7.14	5	0.70	7.56	5	0.66
13	0.00	0	-	0.00	0	-	0.19	0	-	0.19	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	38.52	7	0.18	51.38	60	1.17	80.18	130	1.62	170.08	197	1.16
Total Canada	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Total Unblocked	0.00	0	-	0.00	0	-	1.82	0	-	1.82	0	-
GRAND TOTAL	38.52	7	0.18	51.38	60	1.17	82.00	130	1.59	171.90	197	1.15

1980

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	7.48	0	-	38.98	15	0.38	19.55	2	0.10	66.01	17	0.26
2	0.36	0	-	1.16	0	-	**1.69**	**2**	**1.18**	3.21	2	0.62
3	7.00	0	-	12.41	0	-	20.12	7	0.35	39.53	7	0.18
4	1.46	0	-	10.75	5	0.47	3.42	1	0.29	15.63	6	0.38
5	2.98	0	-	**10.01**	**10**	**0.99**	2.04	0	-	**15.03**	**10**	**0.67**
6	0.00	0	-	1.06	0	-	0.11	0	-	1.17	0	-
7	0.00	0	-	0.80	0	-	0.00	0	-	0.80	0	-
8	0.00	0	-	0.26	0	-	0.00	0	-	0.26	0	-
9	0.00	0	-	0.29	0	-	0.00	0	-	0.29	0	-
10	0.00	0	-	0.57	0	-	0.18	0	-	0.75	0	-
11	0.51	0	-	0.12	0	-	1.67	0	-	2.30	0	-
12	0.00	0	-	0.00	0	-	1.94	0	-	1.94	0	-
13	0.00	0	-	0.00	0	-	0.50	0	-	0.50	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	0.58	0	-	0.58	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	19.79	0	-	76.41	30	0.39	51.80	12	0.23	148.00	42	0.28
Total Canada	0.67	0	-	8.58	4	0.47	0.65	0	-	9.90	4	0.40
Total Unblocked	0.00	0	-	0.00	0	-	1.07	0	-	1.07	0	-
GRAND TOTAL	20.46	0	-	84.99	34	0.40	53.52	12	0.22	158.97	46	0.29

Bold indicates peak WPUE.

Table 31 (contd).

1981

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	6.65	0	-	23.24	5	0.22	19.01	17	0.89	48.90	22	0.45
2	0.36	0	-	0.48	0	-	0.30	0	-	1.14	0	-
3	2.98	0	-	5.34	0	-	13.34	7	0.52	21.66	7	0.32
4	4.22	0	-	15.67	96	6.13	7.11	30	4.22	27.00	126	4.67
5	1.94	0	-	20.98	130	6.20	2.98	0	-	25.90	130	5.02
6	0.00	0	-	1.44	0	-	1.46	0	-	2.90	0	-
7	0.54	0	-	1.67	0	-	1.15	0	-	3.36	0	-
8	0.00	0	-	1.31	0	-	0.00	0	-	1.31	0	-
9	0.00	0	-	0.12	0	-	0.00	0	-	0.12	0	-
10	0.52	0	-	0.00	0	-	0.00	0	-	0.52	0	-
11	0.39	0	-	0.03	0	-	0.28	0	-	0.70	0	-
12	1.86	0	-	0.00	0	-	0.37	0	-	2.23	0	-
13	1.14	0	-	0.00	0	-	0.00	0	-	1.14	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	1.17	0	-	0.00	0	-	0.00	0	-	1.17	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	21.77	0	-	70.28	231	3.29	46.00	54	-	138.05	285	2.06
Total Canada	3.27	2	0.61	3.17	1	0.32	0.00	0	-	6.44	3	0.47
Total Unblocked	8.87	0	-	0.04	0	-	0.00	0	-	8.91	0	-
GRAND TOTAL	33.91	2	0.06	73.49	232	3.16	46.00	54	1.17	153.40	288	1.88

1982

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	9.99	0	-	13.76	94	6.83	5.35	1	0.19	29.10	95	3.26
2	3.70	0	-	2.22	3	1.35	1.21	0	-	7.13	3	0.42
3	0.00	0	-	16.22	13	0.80	3.63	9	2.48	19.85	22	1.11
4	14.27	0	-	8.58	8	0.93	4.02	0	-	26.87	8	0.30
5	19.14	16	0.84	14.07	159	11.30	4.27	3	0.70	37.48	178	4.75
6	15.22	43	2.83	5.38	0	-	1.83	0	-	22.43	43	1.92
7	12.35	75	6.07	3.86	0	-	0.00	0	-	16.21	75	4.63
8	4.90	0	-	1.55	0	-	0.59	0	-	7.04	0	-
9	3.73	2	0.54	3.13	4	1.28	0.48	0	-	7.34	6	0.82
10	0.54	0	-	0.00	0	-	0.43	0	-	0.97	0	-
11	0.00	0	-	4.56	0	-	5.35	1	0.19	9.91	1	0.10
12	0.00	0	-	4.58	2	0.44	8.01	15	1.87	12.59	17	1.35
13	0.00	0	-	1.48	0	-	4.34	12	2.76	5.82	12	2.06
14	0.00	0	-	0.00	0	-	2.46	1	0.41	2.46	1	0.41
15	0.00	0	-	0.00	0	-	0.12	0	-	0.12	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	3.81	0	-	3.81	0	-
18	0.00	0	-	0.00	0	-	2.00	0	-	2.00	0	-
Block Total	83.84	136	1.62	79.39	283	3.56	47.90	42	0.88	211.13	461	2.18
Total Canada	1.80	9	5.00	0.37	18	48.65	4.39	2	0.46	6.56	29	4.42
Total Unblocked	0.36	0	-	0.18	0	-	0.70	0	-	1.24	0	-
GRAND TOTAL	86.00	145	1.69	79.94	301	3.77	52.99	44	0.83	218.93	490	2.24

Table 31 (contd).

1983

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	9.82	0	-	17.99	2	0.11	5.77	0	-	33.58	2	0.06
2	2.91	1	0.34	10.34	9	0.87	1.54	0	-	14.79	10	0.68
3	11.96	0	-	13.22	8	0.61	6.13	3	0.49	31.31	11	0.35
4	7.08	0	-	3.33	0	-	3.65	0	-	14.06	0	-
5	12.05	38	3.15	4.91	0	-	1.11	0	-	18.07	38	2.10
6	6.28	0	-	11.29	17	1.51	3.70	1	0.27	21.27	18	0.85
7	13.92	17	1.22	4.20	8	1.90	2.30	5	2.17	20.42	30	1.47
8	4.92	0	-	3.34	0	-	0.00	0	-	8.26	0	-
9	4.45	0	-	2.78	1	0.36	0.00	0	-	7.23	1	0.14
10	5.22	0	-	9.34	2	0.21	0.79	0	-	15.35	2	0.13
11	2.57	0	-	13.10	7	0.53	5.81	0	-	21.48	7	0.33
12	5.49	0	-	10.69	18	1.68	10.74	8	0.74	26.92	26	0.97
13	0.00	0	-	3.28	3	0.91	8.88	13	1.46	12.16	16	1.32
14	0.00	0	-	0.87	0	-	3.95	0	-	4.82	0	-
15	0.00	0	-	0.00	0	-	3.73	0	-	3.73	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.96	3	3.12	4.29	3	0.70	5.25	6	1.14
18	0.00	0	-	0.00	0	-	4.61	2	0.43	4.61	2	0.43
Block Total	36.67	56	0.65	109.64	76	0.69	67.00	35	0.52	263.31	169	0.64
Total Canada	0.81	3	3.70	0.00	0	-	0.00	0	-	0.81	3	3.70
Total Unblocked	0.60	0	-	1.27	0	-	3.58	0	-	5.45	0	-
GRAND TOTAL	88.08	59	0.67	110.91	76	0.69	70.58	35	0.50	269.57	172	0.64

1984

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	9.46	0	-	16.98	10	0.59	13.93	4	0.29	40.37	14	0.35
2	1.88	0	-	3.80	4	1.05	3.81	1	0.26	9.49	5	0.53
3	3.21	0	-	10.94	2	0.18	17.68	22	1.24	31.83	24	0.75
4	12.60	0	-	5.58	15	2.69	1.85	0	-	20.03	15	0.75
5	16.45	19	1.16	8.77	28	3.19	2.91	4	1.37	28.13	51	1.81
6	8.11	0	-	4.64	9	1.94	2.04	0	-	14.79	9	0.61
7	9.73	0	-	3.73	0	-	0.00	0	-	13.46	0	-
8	2.99	0	-	1.53	0	-	0.00	0	-	4.52	0	-
9	2.92	0	-	3.33	0	-	0.00	0	-	6.25	0	-
10	0.06	0	-	4.53	0	-	0.10	0	-	4.69	0	-
11	2.30	0	-	4.17	0	-	5.57	17	3.05	12.04	17	1.41
12	1.01	0	-	5.63	148	26.29	15.58	37	2.37	22.22	185	8.33
13	5.61	0	-	4.76	2	0.42	5.77	5	0.87	16.14	7	0.43
14	2.19	0	-	2.79	0	-	0.11	0	-	5.09	0	-
15	2.14	0	-	0.00	0	-	0.00	0	-	2.14	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	1.05	0	-	0.75	0	-	1.90	0	-	3.70	0	-
18	0.33	0	-	0.00	0	-	0.00	0	-	0.33	0	-
Block Total	82.04	19	0.23	81.93	218	2.66	71.25	90	1.26	235.22	327	1.39
Total Canada	1.23	2	1.63	2.47	42	17.00	2.43	9	3.70	6.13	53	8.65
Total Unblocked	0.22	0	-	0.37	0	-	0.66	0	-	1.25	0	-
GRAND TOTAL	83.49	21	0.25	84.77	260	3.07	74.34	99	1.33	242.60	380	1.57

Table 31 (contd).

1985

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	10.67	0	-	13.04	7	0.54	7.97	18	2.26	31.68	25	0.79
2	1.67	0	-	4.16	0	-	1.75	0	-	7.58	0	-
3	0.00	0	-	4.90	0	-	12.38	5	0.40	17.28	5	0.29
4	16.75	0	-	10.39	23	2.21	6.22	0	-	33.36	23	0.69
5	17.52	11	0.63	10.89	19	1.74	9.16	0	-	37.57	30	0.80
6	7.31	0	-	7.78	3	0.39	2.09	0	-	17.18	3	0.17
7	8.70	1	0.18	7.08	0	-	2.08	0	-	17.86	1	0.06
8	3.01	0	-	5.33	0	-	0.06	0	-	8.40	0	-
9	0.32	0	-	0.36	0	-	0.00	0	-	0.68	0	-
10	0.16	0	-	0.18	0	-	0.25	0	-	0.59	0	-
11	0.00	0	-	0.19	0	-	3.00	27	9.00	3.19	27	8.46
12	0.00	0	-	3.08	0	-	13.25	7	0.53	16.33	7	0.43
13	0.00	0	-	0.00	0	-	6.40	2	0.31	6.40	2	0.31
14	0.00	0	-	0.00	0	-	2.09	1	0.48	2.09	1	0.48
15	0.00	0	-	0.00	0	-	1.00	0	-	1.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	2.69	0	-	2.69	0	-
18	0.00	0	-	0.00	0	-	2.90	0	-	2.90	0	-
Block Total	66.11	12	0.18	67.38	52	0.77	73.29	60	0.82	206.78	124	0.60
Total Canada	0.91	0	-	2.30	15	6.52	1.96	0	-	5.17	15	2.90
Total Unblocked	0.00	0	-	0.09	0	-	0.78	0	-	0.87	0	-
GRAND TOTAL	67.02	12	0.18	69.77	67	0.96	76.03	60	0.79	212.82	139	0.65

1986

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	3.02	0	-	20.77	2	0.10	15.06	15	1.00	38.85	17	0.44
2	0.00	0	-	4.69	0	-	5.31	2	0.38	10.00	2	0.20
3	0.00	0	-	6.67	0	-	8.59	4	0.47	15.26	4	0.26
4	11.90	0	-	17.10	16	0.94	4.23	3	0.71	33.23	19	0.57
5	13.29	19	1.43	17.83	42	2.36	0.00	0	-	31.12	61	1.96
6	6.83	1	0.15	10.21	3	0.29	2.51	0	-	19.55	4	0.20
7	4.46	0	-	9.87	1	0.10	0.00	0	-	14.33	1	0.07
8	3.31	0	-	2.62	0	-	0.00	0	-	5.93	0	-
9	2.58	0	-	2.91	0	-	0.14	0	-	5.63	0	-
10	0.00	0	-	2.01	0	-	0.20	0	-	2.21	0	-
11	0.00	0	-	2.20	1	0.45	3.80	0	-	6.00	1	0.17
12	0.00	0	-	4.40	0	-	12.09	11	0.91	16.49	11	0.67
13	0.00	0	-	15.57	0	-	15.71	2	0.13	31.28	2	0.06
14	0.00	0	-	9.30	1	0.11	7.80	1	0.13	17.10	2	0.12
15	0.00	0	-	6.45	0	-	0.39	0	-	6.84	0	-
16	0.00	0	-	0.44	0	-	0.00	0	-	0.44	0	-
17	0.00	0	-	6.68	0	-	7.35	0	-	14.03	0	-
18	0.00	0	-	3.08	0	-	2.70	0	-	5.78	0	-
Block Total	45.39	20	0.44	142.80	66	0.46	85.88	38	0.44	274.07	124	0.45
Total Canada	1.35	21	15.56	1.63	13	7.98	0.00	0	-	2.98	34	11.41
Total Unblocked	0.04	0	-	1.80	0	-	3.63	0	-	5.47	0	-
GRAND TOTAL	46.78	41	0.88	146.23	79	0.54	89.51	38	0.42	282.52	158	0.56

Table 31 (contd).

TOTAL

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	76.34	0	-	169.09	137	0.81	142.04	145	1.02	387.83	282	0.73
2	13.03	1	0.08	29.35	16	0.55	18.78	5	0.27	61.16	22	0.36
3	25.15	0	-	70.35	23	0.33	89.23	84	0.94	184.73	107	0.58
4	79.91	0	-	82.79	164	1.98	34.75	44	1.27	197.45	208	1.05
5	83.37	103	1.24	92.72	441	4.76	22.47	7	0.31	**198.56**	**551**	**2.77**
6	48.88	51	1.04	47.27	36	0.76	14.76	1	0.07	110.91	88	0.79
7	**49.70**	**93**	**1.87**	32.57	9	0.28	5.53	5	0.90	87.80	107	1.22
8	19.13	0	-	15.94	0	-	0.65	0	-	35.72	0	-
9	14.00	2	0.14	12.92	5	0.39	0.62	0	-	27.54	7	0.25
10	6.86	0	-	16.63	2	0.12	1.95	0	-	25.44	2	0.08
11	5.77	0	-	24.37	8	0.33	**26.77**	**45**	**1.68**	56.91	53	0.93
12	8.36	0	-	**28.80**	**168**	**5.83**	69.12	83	1.20	106.28	251	2.36
13	6.74	0	-	25.09	5	0.20	41.79	34	0.81	73.62	39	0.53
14	2.19	0	-	12.96	1	0.08	16.41	3	0.18	31.56	4	0.13
15	2.14	0	-	6.45	0	-	5.24	0	-	13.83	0	-
16	0.00	0	-	0.44	0	-	0.00	0	-	0.44	0	-
17	2.22	0	-	8.39	3	0.36	20.62	3	0.15	31.23	6	0.19
18	0.33	0	-	3.08	0	-	12.21	2	0.16	15.62	2	0.13
Block Total	444.13	250	0.56	679.21	1018	1.50	523.30	461	0.88	1646.64	1729	1.05
Total Canada	10.04	37	3.69	18.52	93	5.02	9.43	11	1.17	37.99	141	3.71
Total Unblocked	10.09	0	-	3.75	0	-	12.24	0	-	26.08	0	
GRAND TOTAL	464.26	287	0.62	701.48	1111	1.58	544.97	472	0.87	1710.71	1870	1.09

- In 1980, there were no bowheads seen in August, relative abundance was highest in block 5 in September, and block 2 in October
- In 1981, bowheads were not seen in August, highest abundance was calculated for block 5 in September, and block 4 in October
- In 1982, bowhead relative abundance was highest in block 7 in August, block 5 in September, and block 13 in October
- In 1983, bowhead relative abundance was highest in block 5 in August, block 17 in September, and block 7 in October
- In 1984, bowhead relative abundance was highest in block 5 in August, block 12 in September, and block 11 in October
- In 1985, bowhead relative abundance was highest in block 5 in August, block 4 in September, and block 11 in October
- In 1986, bowhead relative abundance was highest in block 5 in August and September, and block 1 in October

Overall (1979-86), highest abundance indices (WPUE) in the Alaskan Beaufort Sea were calculated for block 7 in August, block 12 in September, and block 11 in October (Table 31). Highest abundance in the Chukchi Sea was calculated for block 17 in September and block 13 in October. These patterns of change in bowhead distribution and relative abundance over time indicate that whales are generally found somewhat offshore in the eastern Alaskan Beaufort Sea in August, in coastal blocks across the Alaskan Beaufort and northeastern Chukchi Sea in September, and somewhat offshore in the central and western Alaskan Beaufort Sea and Chukchi Sea survey blocks in October. Notably, total peak abundance indices in the Chukchi Sea were five times lower than peak indices calculated for the Alaskan Beaufort Sea survey blocks. Differences in abundance indices calculated for each survey block between years reflect the annual variation in the distribution and timing of whale movements during the migration.

Deriving a density estimate for a particular area is useful when assessing a species use of that area over time. Bowhead densities were calculated for survey blocks only in 1985 and 1986. Highest bowhead density for both years combined (Figure 29) was calculated for block 5 in August (0.112 whales/100 km^2) and September (0.237 whales/100 km^2). Highest density in October for 1985 and 1986 combined was in block 1 (0.141 whales/100 km^2). Density estimates have been calculated for bathymetrically defined subregions in the Alaskan Beaufort Sea since 1979, as described in Appendix B.

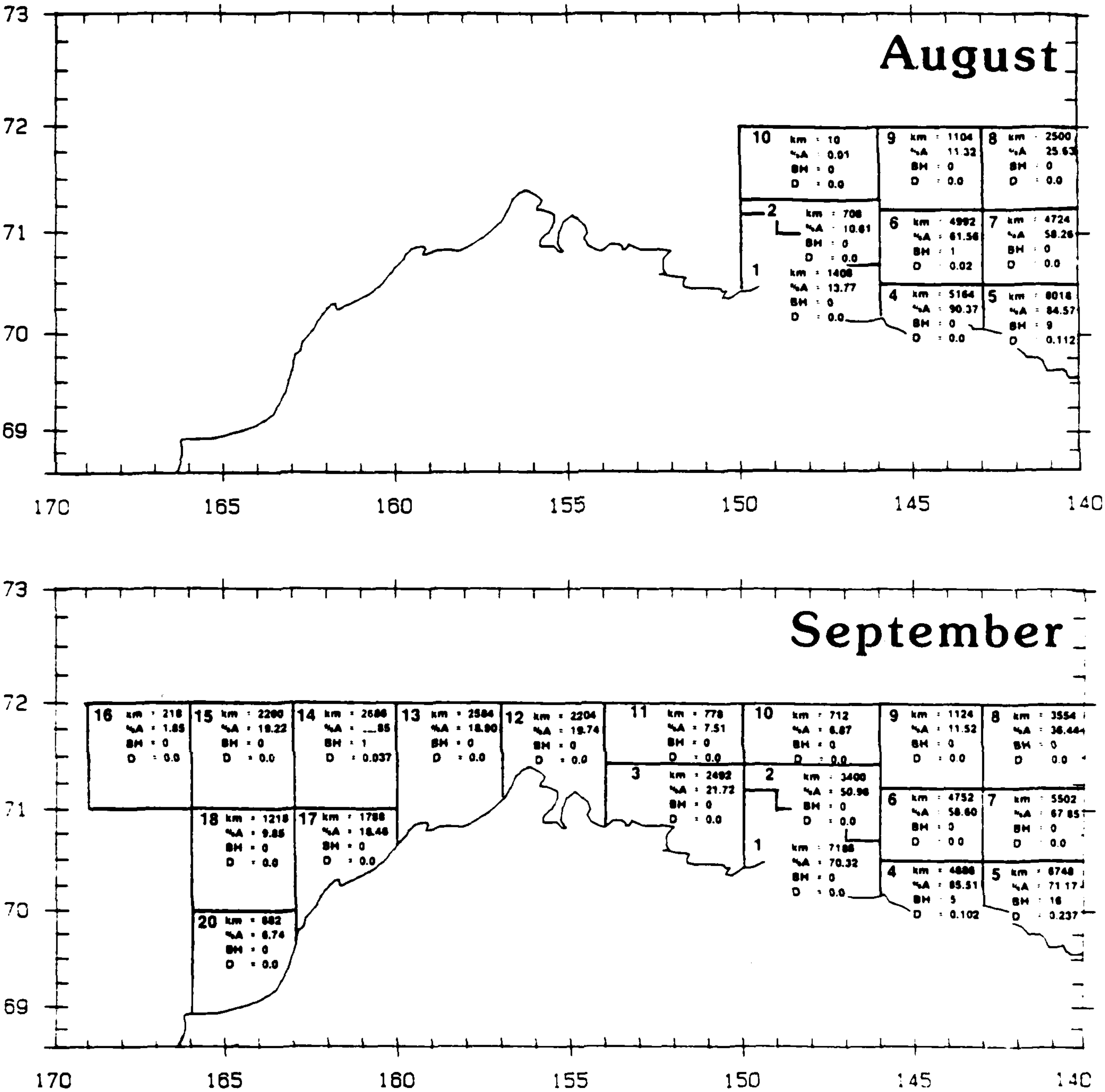
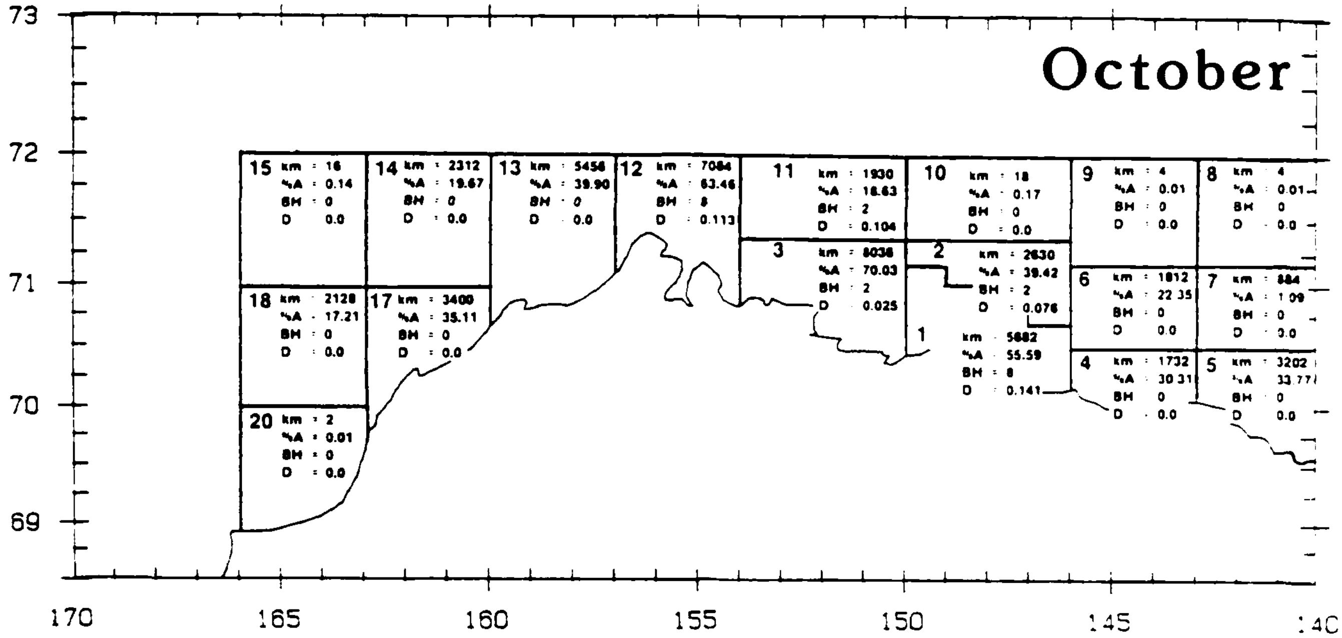


Figure 29. Monthly and seasonal bowhead density estimates, 1985-86: August; September;



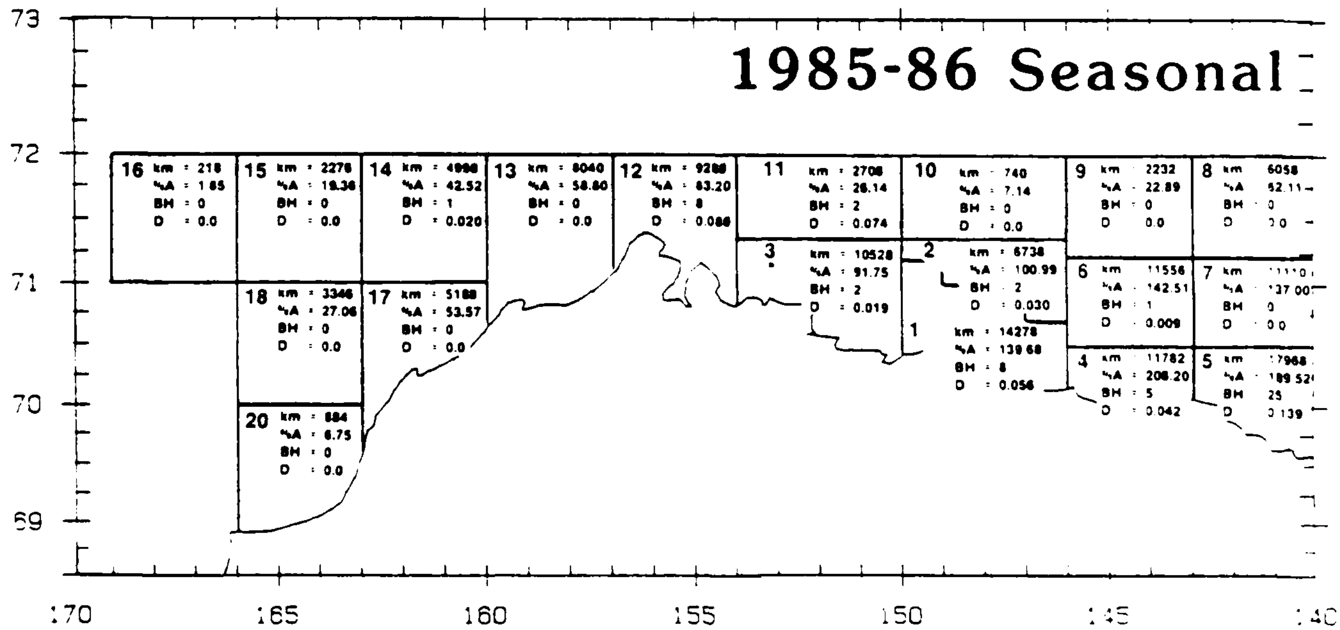


Figure 29 (contd). October; 1985-86 seasonal.

Migration Route, Timing, and Habitat Relationships

a. Migration Route as Defined by Median Water Depth at Bowhead Sightings

The fall bowhead migration route passes near or through areas off Alaska's North Slope that are designated for, or currently involved in, oil and gas exploration and development (see Figure 28). Recently, concern has focused on the potential offshore displacement of the fall bowhead migration route by OCS oil and gas development activity. It was determined that one means of addressing this concern was to analyze bowhead sighting data for potential shifts in migratory route. A simple statistic was needed to define an axis of the bowhead fall migration route to address the question of potential shifts in the migration route. Median water depth for bowhead sightings made on random north-south line transect surveys was the statistic chosen because it (a) adequately defined the observed migratory axis as the depth contour such that half the sightings were at shallower (or equal) depths and half the sightings were at deeper (or equal) depths, (b) is a robust statistic and as such it is insensitive to unusually large or small depth values, to nonuniform aerial survey coverage, or to skewed distributions of data, and (c) was easy to compute from the existing data base. The analysis protocol specifying the use of median water depth to detect interannual shifts in the bowhead migration route is described in Chapters 4.2.3 and 5.3.3 of "Beaufort Sea Monitoring Program Workshop Synthesis and Sampling Design Recommendations" (Houghton et al., 1984).

The hypotheses tested via median depth analysis were prescribed in Houghton et al. (1984) as

Ho_1: The axis of the fall migration of bowhead whales will not be altered during periods of increased OCS activities in the Alaskan Beaufort Sea.

Ho_2: Changes in bowhead migration patterns are not related to OCS oil and gas development activity.

Because of the bathymetry of the Alaskan Beaufort Sea, a seaward displacement of the fall migration route would be represented, via this analysis, as a shift to a deeper median depth.

Median depth at bowhead sightings was analyzed for the Alaskan Beaufort Sea study area between 141°W and 157°W, as well as for each of the four regions (A-D) utilized in density analysis (Figure 30). Region A extended from 153°30'W to 157°00'W, region B from 150°00'W to 153°30'W, region C from 146°00'W to

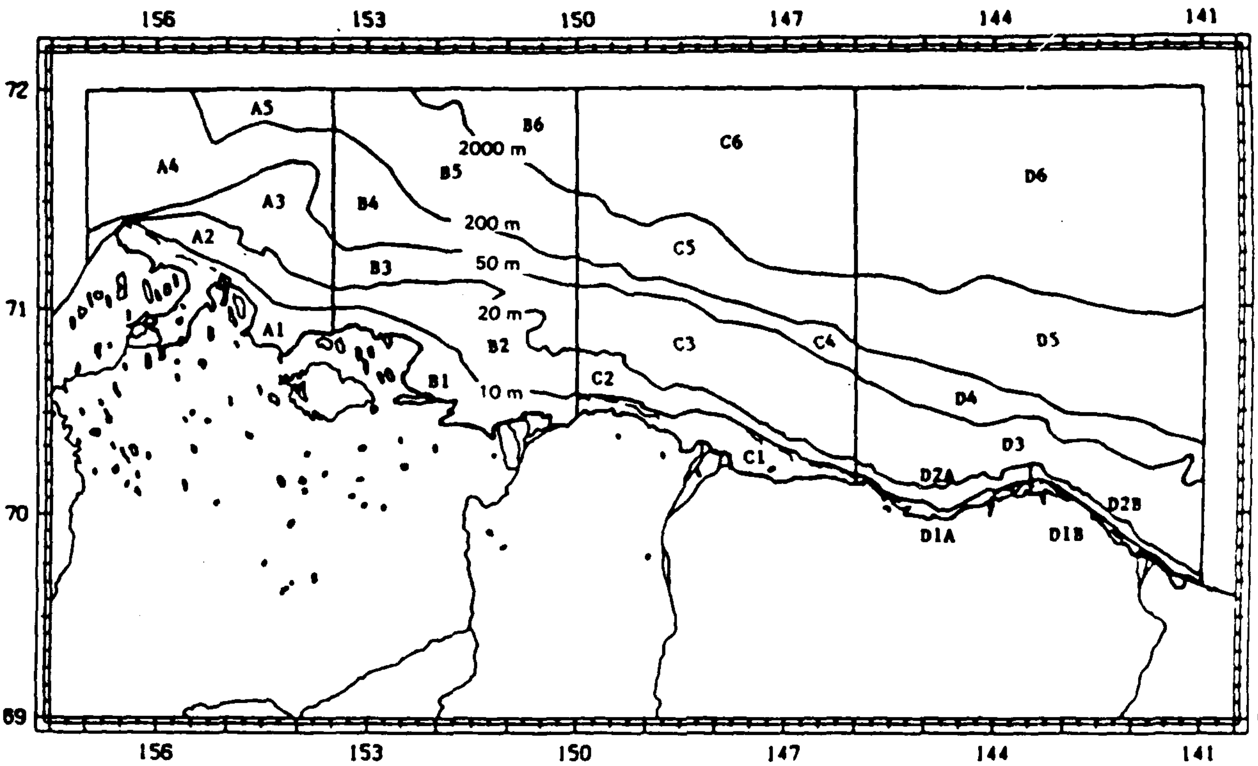


Figure 30. Four regions of the Alaskan Beaufort Sea study area stratified by contour intervals of 10 m, 20 m, 50 m, 200 m, and 2000 m.

150°00'W, and region D extended from 141°00'W to 146°00'W. The depth at each bowhead sighting in the 1979-86 data base was derived using the computer program DEPTH, which assigned a metric depth value averaged over a 5 nmi of latitude by 20 nmi of longitude (approximately 9.25 km x 37 km) segment of the Beaufort Sea between 141°W and 157°W offshore to 72°N. This scaling assigns depth to sighting locations with an accuracy of approximately ± 3.5 m over most of the study area. At the shelf break between 100 m and 1000 m in regions B and C, and between 10 m and 100 m at 156°30'W in region A, the accuracy was approximately ±20 m. Values assigned to each segment were read off NOAA Provisional Chart 16004 when the DEPTH software was written. After depth values for all bowhead sightings were standardized across all years using DEPTH, it was determined that a 5-m shift in depth would correspond roughly to a 2-km displacement.

The bowhead sighting data base was sorted such that only sightings made on random transect lines were stored onto a separate data file (MEDEPTH1).

Sightings made during search surveys or enroute to survey blocks were omitted from the data file because such sightings do not represent a random sample of depths of all possible sightings. The median depth of sightings rather than of individual whales was used because each sighting represents an independent random observation, a necessary prerequisite to the derivation of confidence intervals for the sample median. To insure that the analysis was not biased by disregarding group size at sightings, the mean depth at sightings of single whales was compared to mean depth at sightings of two or more whales. There was no significant difference in depth at sightings of single whales when compared to depth at sightings of two or more whales for any year 1979-86. There was a weak trend for depth at sightings of ≥ 2 whales to be deeper than depth at single whale sightings in 1982 ($p < 0.20$) and 1986 ($p < 0.10$), but all other years showed no difference ($p > 0.50$) in depth between sightings, thus water depth and group size appeared to be independent.

Overall, bowheads sighted on random transects in August were farther offshore and, therefore, in deeper water than whales seen during September and October (Figure 31). These whales were either part of an early offshore migratory component (Ljungblad et al., 1983), or were an extension of the summering population generally thought to be confined to the Canadian Beaufort Sea (Fraker and Bockstoce, 1980). Because of their offshore distribution and (except in 1982) lack of significant clustering about westerly swimming directions, August bowhead sightings probably do not represent whales likely to be affected by current nearshore OCS development activities and were, therefore, eliminated from subsequent analysis. The MEDEPTH1 data file was sorted such that only bowhead sightings made on random transects in September and October were stored (MEDEPTH2). The MEDEPTH2 depth values were then ranked from lowest to highest values and a sample median, 99 percent C.I. and overall sample range were tabulated.

The 99 percent C.I. was defined as

$$L_1 = X_{C+1} \text{ : lower limit}$$
$$L_2 = X_{n-C} \text{ : upper limit}$$

Where $\alpha(2) = 0.01$, C is determined from a table of critical values (Zar, 1984; Table B-26) when sample size $n \geq 8$. Confidence intervals were calculated at the 1 percent level to reduce the probability of incorrectly asserting that a change in migration

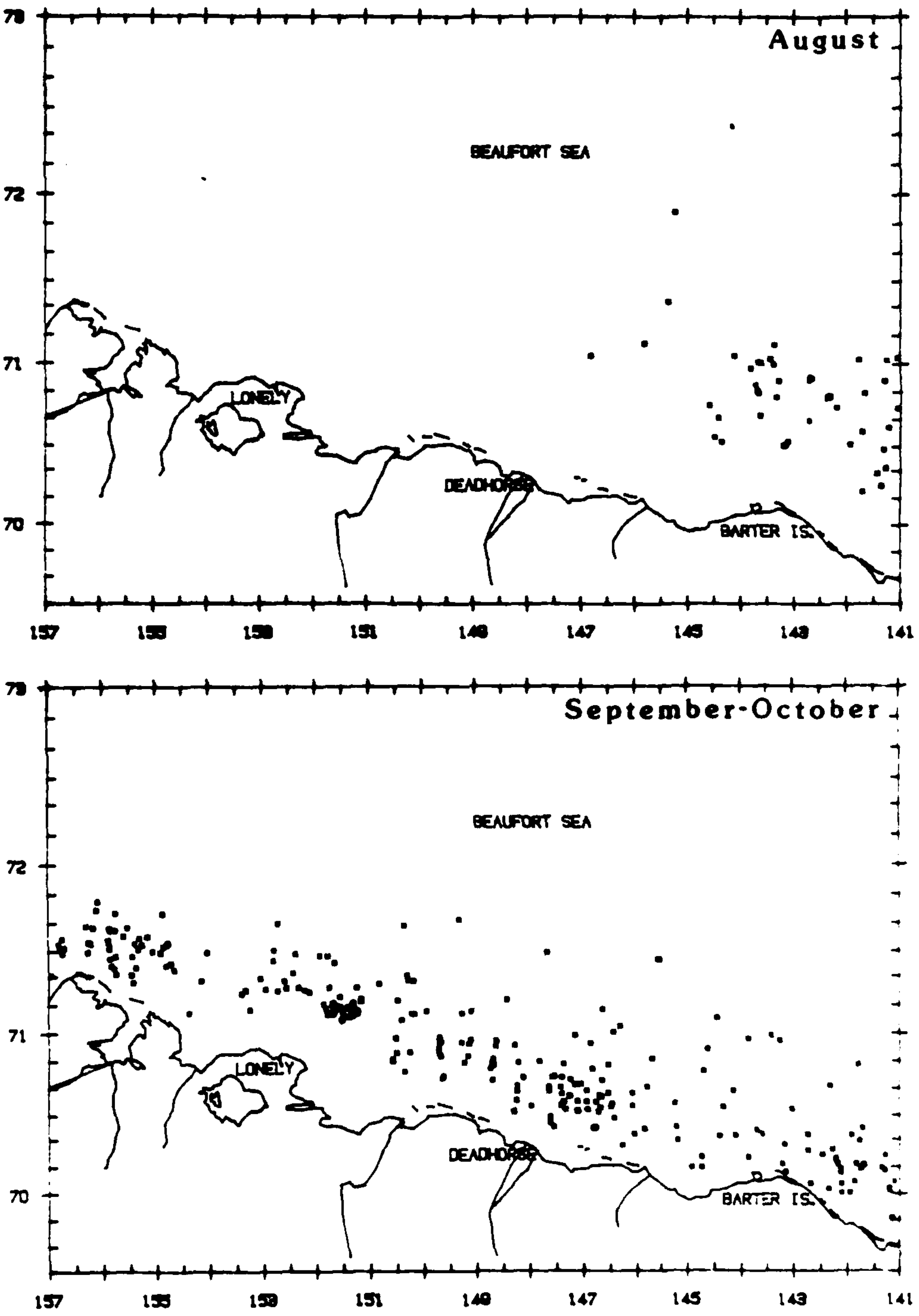


Figure 31. Distribution of bowhead sightings on random transect surveys in the Alaskan Beaufort Sea, 1979-86: 49 sightings, August; 265 sightings, September-October.

route had occurred based on comparing any one year to six others. For example, the probability of incorrectly determining a change occurred based on 1 of 5 tests is approximately 23 percent if tested at the 5 percent level, but only about 5 percent if tested at the 1 percent level (Houghton et al., 1984).

The Mann-Whitney test was then used to address the question of potential shifts in the axis of the bowhead whale fall migration route. The Mann-Whitney test is a nonparametric procedure performed on ranked samples where U and U' are calculated as:

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1$$

$$U' = n_1 n_2 - U$$

where, n_1 = the smaller of the two samples being compared, if sample sizes are unequal

n_2 = the second sample set

R_1 = sum of the ranks of the n_1 sample

If either U or U' is as great or greater than the tabularized critical value at the chosen level of significance, the difference between the samples is significant. If the size of the smaller sample exceeds 20 or the size of the larger sample exceeds 40, the distribution of U approaches the normal distribution and a Z value is compared to the critical value t_α, where Z is calculated as:

$$Z = \frac{|U - \mu U| - 0.5}{\sigma U}$$

after μU and σU have been derived from the sample sizes as

$$\mu U = \frac{n_1 n_2}{2} \quad ; \quad \sigma U = \sqrt{\frac{n_1 n_2(N+1)}{12}}$$

A series of Mann-Whitney paired comparisons were made on annual depth values derived from the MEDEPTH2 data file, with each year compared to all others such that annual and/or overall shifts in migration route over the 1979-86 study period could be evaluated. Subsequently, the MEDEPTH2 file was sorted by region (A-D) and a series of paired comparisons were calculated for each region such that annual variations or potential shifts in median depth could be assessed for these smaller areas.

A total of 265 bowhead sightings have been made during random transect surveys conducted in September and October since 1979. The timing and coverage of fall aerial surveys have changed from year to year with resultant shifts in areas surveyed, the amount of effort allotted to transect surveys, and therefore, the number of sightings made while on transect. For example, in 1979 and 1980 transect surveys were conducted primarily in or near the proposed state/federal oil lease areas (Figure 1: blocks 1 and 3), with search surveys flown in blocks 4 and 5. In 1981, attempts were made to conduct both behavioral studies (in blocks 4 and 5) and transect surveys (in blocks 1 and 3) from a single aircraft. The result was that prior to 1982, there was almost no survey effort north of the 200-m isobath, little effort west of 154°W, and relatively few sightings while on random transect lines. Since 1982, survey efforts have included survey blocks 1 through 12 (see Figure 1). As a result, more transect surveys were flown over the entire study area, and relatively more sightings were made while on random transects from 1982-86.

The annual median water depth for bowhead sightings on transect surveys conducted in September and October ranged from 20 m in 1980 to 145 m in 1983 (Table 32). The 1979-81 and 1984-86 data were most similar, with a median depth range of 20 to 29 m and 99 percent confidence interval (C.I.) overlap within 18-40 m. Although the overall median depth for the 1982 sample was 38 m, the 99 percent confidence interval of 22-40 m overlapped that of 1979-81 and 1984-86 data. The median depth and confidence interval for 1983 data (145 m, 49-732 m) were deeper than that for any other year.

It should be noted that the sample size, sample median, and 99 percent C.I. for the 1982 data cited in Houghton et al. (1984) is discrepant with that published here. Their larger sample size ($n = 103$) for 1982 September-October sightings is likely the result of using all data in Ljungblad et al. (1983) Appendix A, for which a sighting distance was listed. Sorting data by this method would result in the inclusion of sightings made on other than random transects, since the listing of a sighting distance in the appendix tables is **not** confined to whales seen on random transect.

A plot of annual median depth contours across the Alaskan Beaufort Sea demonstrates an overlap of the migration route with eastern (approx. 141°W to 147°W) OCS oil and gas lease areas, similar to that depicted in the distribution analysis (Figure 32). There appeared to be little variation in annual median depth across years 1979-86 as determined by the Mann-Whitney test. The only year that

Table 32. Median, confidence interval, and overall range of water depth at bowhead sightings in the Alaskan Beaufort Sea, September-October 1979-86.

YEAR	(n)	MEDIAN	C.L(99%)	RANGE
1979	(33)	29 m	18-35 m	11-42 m
1980	(12)	20 m	18-40 m	11-40 m
1981	(13)	29 m	15-40 m	15-46 m
1982	(51)	38 m	22-40 m	7-2799 m
1983	(34)	145 m	49-732 m	5-2698 m
1984	(60)	28 m	20-40 m	5-466 m
1985	(17)	29 m	9-73 m	7-225 m
1986	(45)	25 m	18-38 m	6-519 m

was significantly different ($p < 0.001$) from all other years was 1983 (Table 33). The observed migratory route was farther offshore and in deeper water in 1983 than in all other years (Figure 32 and 33). The only other case of significant difference of median depth between years was the 1979 and 1982 samples. The level of significance ($p < 0.05$) was not nearly as great as that for comparisons of any year with 1983 data (Table 33). This observed difference in median depth was probably related to diffe:ences in flight effort (i.e., surveys were flown offshore over deeper water in 1982, but not in 1979). When sightings with corresponding depths deeper than 200 m were de'-ted from the 1982 data ($n = 3$), the resultant median depth for 1982 (33 m) was not significantly different than 1979 ($U = 960.5$, $Z = 1.62$, $p < 0.20$).

The cause for the offshore migratory route in 1983 is unclear. Seismic exploration by geophysical vessels has been proposed as a disturbance source that might displace the bowhead migration (Albert, in Houghton et al., 1984). This seems an unlikely cause for the offshore distribution in 1983 however, because geophysical vessels were forced to operate primarily in Canadian waters or were confined to coastal Alaskan waters by the heavy-ice conditions prevalent that year. Beaufort Sea ice coverage in 1983 was very heavy, similar to 1980 and to a lesser extent 1985 conditions, but much heavier than conditions in 1982, 1984, and 1986. Although geophysical vessels did not often use their air guns to conduct seismic

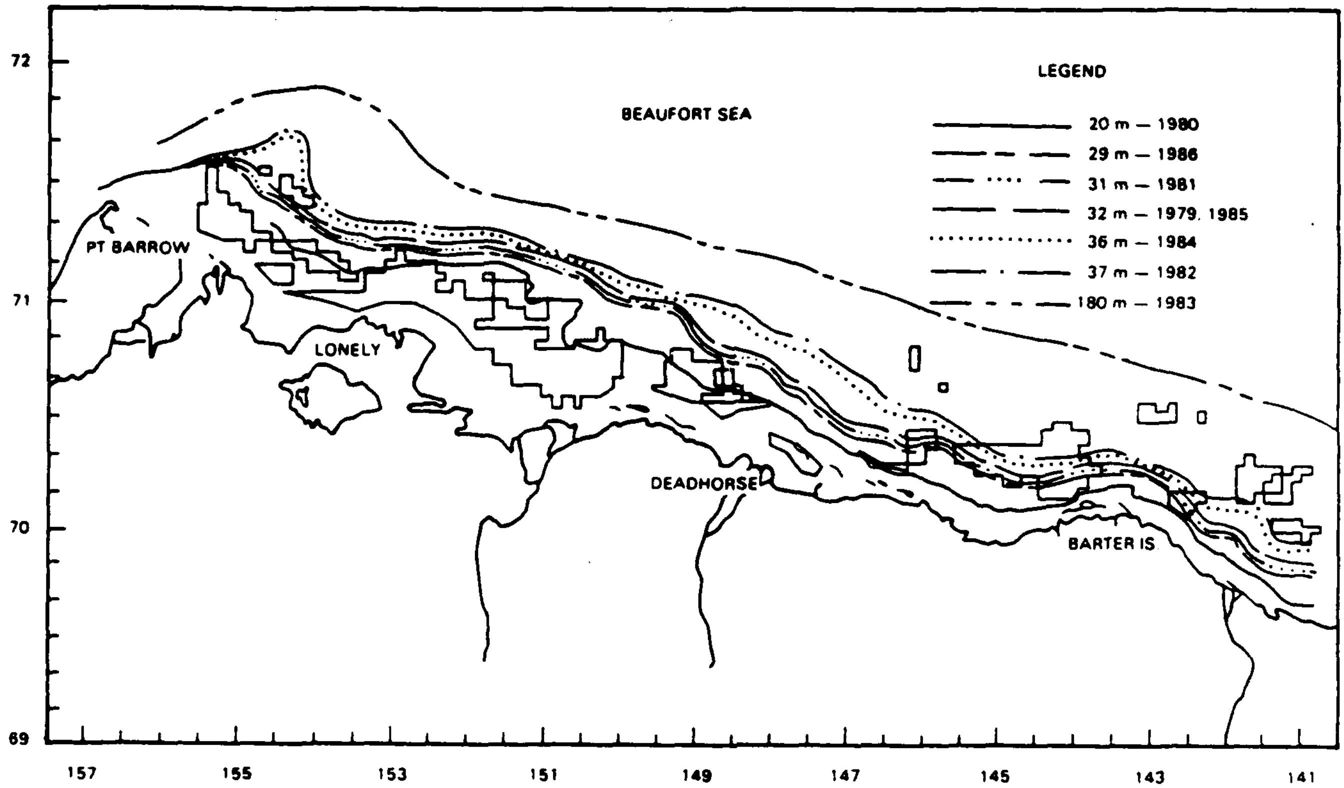


Figure 32. Annual median water depth contours depicting the bowhead migration route across the entire Alaskan Beaufort Sea, September-October 1979-86. Outlined areas depict OCS oil and gas lease areas within the Beaufort Sea Planning Area of the Alaskan Beaufort Sea.

surveys in 1983 due to the restrictive ice, the ships themselves were generating noise in the near-shore waters. Measurements of geophysical vessel peak engine noise levels in the 100- to 200-Hz frequency band include 104 dB re $1uPa^2/Hz$ for a vessel at 1.4 km, 80 dB re $1uPa^2/Hz$ for a vessel 38 km away, and 78 dB re $1uPa^2/Hz$ for a vessel 43 km away (Moore et al., 1984). Bowheads have been observed to avoid vessels of a variety of sizes when approached to within 1-4 km, and their avoidance of boats, although seemingly of short duration, has been described as more dramatic and consistent than to any other industrial activity studied (Richardson et al., 1985b). However, the magnitude of displacement (roughly 45 km) of the 1983 fall migration is certainly greater than that experienced or expected if caused by vessel disturbance. Even when bowheads were directly approached by geophysical vessels that were firing their air guns during experimental trials, behavior disturbance was not elicited until the vessels were within about 7.5 km of the whales, and was relatively short term

Table 33. Results of the Mann-Whitney test for comparisons of median water depth at bowhead sightings in the Alaskan Beaufort Sea, September-October 1979-86.

	1979 (n=33)	1980 (n=12)	1981 (n=13)	1982 (n=51)	1983 (n=34)	1984 (n=60)	1985 (n=17)
1980	U=233 $p \leq 0.50$						
1981	U'=220.5 $p \leq 0.50$	U=95 $p \leq 0.50$					
1982	**U=1059.5** **Z=1.99** **$p < 0.05$**	U=414.5 Z=1.89 $p < 0.10$	U=409 Z=1.284 $p < 0.20$				
1983	**U=975.5** **Z=5.19** **$p < 0.001$**	**U=354** **$p < 0.001$**	**U=383.5** **$p < 0.001$**	**U'=1376** **Z=4.56** **$p < 0.001$**			
1984	U=1117.5 Z=1.02 $p \leq 0.50$	U=441 Z=1.22 $p \leq 0.50$	U=436 Z=0.66 $p \leq 0.50$	U'=1618 Z=0.52 $p \leq 0.50$	**U=1656.5** **Z=5.00** **$p < 0.001$**		
1985	U'=317.5 $p \leq 0.50$	U=123 $p \leq 0.50$	U=120.5 $p \leq 0.50$	U=471.5 Z=0.53 $p \leq 0.50$	**U=464** **$p \leq 0.001$**	U=516.5 Z=0.07 $p \leq 0.50$	
1986 (n=45)	U'=778.5 Z=0.36 $p \leq 0.50$	U=287 Z=0.32 $p \leq 0.50$	U'=305 Z=0.22 $p \leq 0.50$	U=1388 Z=1.76 $p < 0.10$	**U=1289** **Z=5.18** **$p < 0.001$**	U=1550 Z=1.29 $p < 0.20$	U'=427 Z=0.69 $p \leq 0.50$

Bold indicates comparisons that were statistically significant.

($\leq$60 min) (Ljungblad et al., 1985b). Displacement due to oil and gas activities other than vessels also seems unlikely, however, as ice conditions in 1983 forced many such activities to be curtailed.

There is little quantitative information available on displacement of large whales by human activities. Although gray whales (Eschrichtius robustus) were apparently displaced from a wintering breeding lagoon off Baja California, Mexico, by increased ship traffic (Gard, 1974; Reeves, 1977), they returned when ship traffic abated (Bryant et al., 1984). It has been suggested that the gray whale migration has been displaced offshore by human activities, especially in the southern California Bight (Rice, 1965; Dohl and Guess, 1979), but Evans (1982)

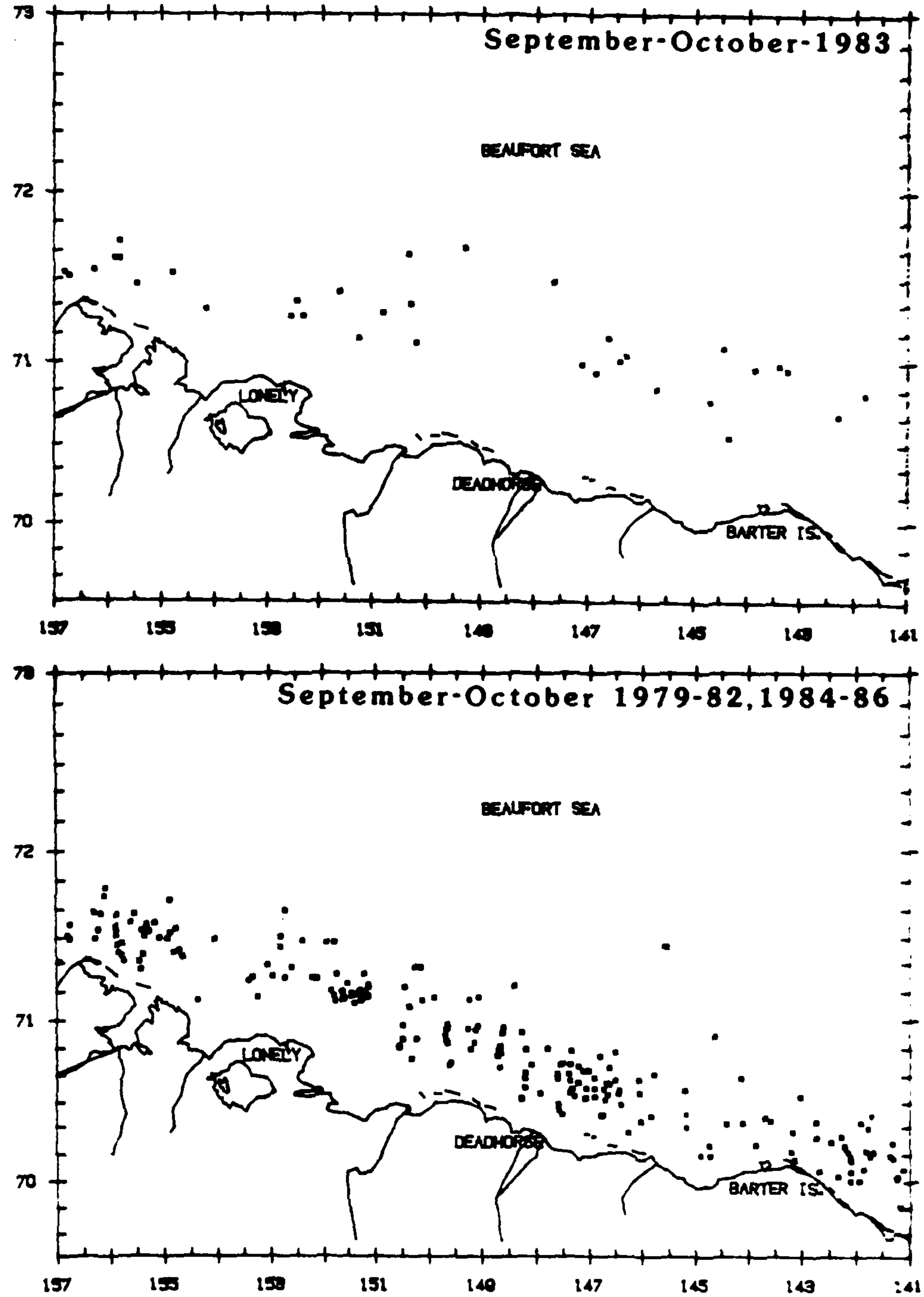


Figure 33. Distribution of 34 bowhead sightings September-October 1983, and 231 sightings September-October 1979-82 and 1984-86.

noted that this potential shift has been documented during a time when the gray whale population appears to be increasing and the apparent shift offshore may be a function of increased population size or other reasons unrelated to disturbance. Cowles et al. (1981) noted that gray whales have continued to migrate along the western coast of North America despite increases in vessel traffic and other potentially disturbing activities. Additional instances where human activities have been thought to impact whale distribution include the breeding and feeding areas of north Pacific humpback whales (Megaptera novaeangliae) in Hawaii (Norris and Reeves, 1978; Bauer and Herman, 1986) and Alaska (Baker et al., 1983); blue (Balaenoptera musculus) and fin (Balaenoptera physalus) whales in the St. Lawrence river (Macfarlane, 1981); and minke whales (Balaenoptera acutorostrata) off Japan (Nishiwaki and Sasao, 1977). In all of the above cases, however, displacements have not been convincingly demonstrated (all but Bauer and Herman, 1986, were reviewed by Richardson et al., 1983).

The offshore distribution of bowheads in 1983 may have been indirectly related to heavy-ice cover. The influence of ice cover on the axis of the bowhead migration, as defined by median depth, appears to be an indirect one and may be related to ice effects on productivity, or to physical oceanographic factors causing ice to be relatively lighter near the 145-m isobath than over shallower water. When median depth was related to average-ice cover observed during random transect survey and average-ice cover at random bowhead sightings for the September-October period of the 1981-86 survey seasons (Table 34), neither overall ice cover nor ice cover at bowhead sightings were significantly correlated with median depth ($r = 0.415$ and $r = 0.530$ respectively; $p > 0.50$). In other words, ice conditions did not appear to directly affect the annual median depth "axis" of the migration. The influence of heavy-ice cover on the productivity of bowhead prey communities over the continental shelf, however, may have contributed to the offshore distribution of bowheads observed in 1983. Between 1979-84, feeding bowheads were seen along the migration route in significantly shallower water and lighter ice cover than nonfeeding whales (Ljungblad et al., 1986a). Prey abundance depends upon light-dependent primary productivity. Ice deflects and diffuses incident light and in this way limits productivity (Schell et al., 1982). Therefore, 1983 prey abundance in the Alaskan Beaufort Sea may have been relatively low. The resultant lack of feeding opportunities may have had the secondary effect of displacing the migration offshore over deeper water. This suggestion of ice-

Table 34. Median water depth (m), average overall ice cover (%) and average-ice cover (%) at bowhead sightings, September-October 1981-86.

	Median Depth	Overall Ice Conditions			Ice Conditions at Sightings			Welch's t' Comparison of Overall Ice Conditions with Ice Conditions at Bowhead Sightings
		$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n	
1981	29	64	32	465	68	27	13	$t' = 0.50$, $p > 0.50$
1982	38	25	45	649	16	40	51	$t' = 1.41$, $p < 0.20$
1983	145	64	34	1004	65	27	34	$t' = 0.20$, $p > 0.50$
1984	28	50	47	1028	31	39	60	$t' = 3.63$, $p < 0.001$
1985	29	57	44	636	35	44	17	$t' = 2.14$, $p < 0.05$
1986	25	18	30	950	0	2	45	$t' = 17.61$, $p < 0.001$
1981-86		45	46	4732	29	40	220	$t' = 5.85$, $p < 0.001$

All data from random transect lines only.

related effects on bowhead distribution via the impact of ice cover on productivity is speculative at best as there have been no comprehensive studies to determine this relationship. An alternate suggestion is that during the heavy-ice year of 1983 (and possibly 1980), bowheads encountered relatively lighter-ice conditions along the 145-m isobath as a result of the effects of prevailing currents and wind on ice cover. Each spring, an east-west lead system develops along a shear zone in the Beaufort Sea, and most whales are seen in or near this lead (Braham et al., 1980; Ljungblad et al., 1986c). Oceanographic conditions similar to those that influence spring ice habitat may have caused ice conditions along the 145-m isobath to be more broken and/or relatively lighter than elsewhere and so influenced bowhead distribution by providing less restrictive migrating conditions. Although ice cover at random bowhead sightings in 1983 was not significantly lighter (65%) than average-ice cover observed on random transects (64%, $t' = 0.20$, $p > 0.50$; Table 34), subtle differences in ice cover or make up (i.e., more broken ice) may have gone undetected because environmental data are updated only every 10 minutes (i.e., roughly every 40 km) in lieu of sighting data during random transect surveys. A narrow (≤ 2 km) lead-type channel of relatively lighter-ice cover, or changing ice composition, would not be definitively described via these methods.

Bowheads may generally prefer areas of relatively lighter-ice cover when migrating, although annual comparisons of overall ice conditions and ice conditions at random sightings did not uniformly support this contention (Table 34). In 1981-83, ice conditions at bowhead sightings were not significantly lighter than overall ice conditions on random transects. Bowheads were found in significantly lighter ice in 1984 ($t' = 3.63$, $p < 0.001$), 1985 ($t' = 2.14$, $p < 0.05$), and 1986 ($t' = 17.61$, $p < 0.001$), however, than overall conditions for those years. When data were pooled over six seasons (1981-86), average-ice conditions recorded on random transects were significantly heavier (45%) than ice conditions at random bowhead sightings (29%; $t' = 5.85$, $p < 0.001$), indicating that whales may seek out areas of relatively lighter ice during the fall migration.

To assess possible shifts in migration route over smaller areas, the median water depth, 99 percent confidence interval, and overall depth range were calculated for each of the 4 regions (see Figure 30) of the Beaufort Sea study area (Table 35, Figure 34). There were no bowhead sightings while on transect in region A in 1979-81, nor in region D in 1980 due to aforementioned annual variations in flight effort. Annual median water depth in region A ranged from 18 m in 1984 and 1986 to 113 m in 1983. The 99 percent confidence interval calculated for 1983 (5-154 m) encompassed that for 1984 (13-22 m). There were too few sightings in region A in 1982, 1985, and 1986 to calculate a confidence interval. The relatively deep median depth for the 1983 sample was consistent with the overall offshore distribution of whales discussed earlier, but was not significantly different from any other year (Table 36). In region B, annual median water depth ranged from 13- to 48-m (Table 35, Figure 34). Surprisingly, the median depth found in the 1983 sample was not significantly different than for 1981-86 samples, but was significantly deeper than that of 1979-80 (Table 36). In addition, median depth for 1984 sightings in region B was significantly deeper than those for 1979. As previously mentioned, flight effort extended farther north and over deeper water in 1982-86 than in 1979-81. In 1984, depth at sightings in region B ranged from 11 m to 55 m, and in 1979 from 18 m to 29 m, such that the difference in annual median depth between these two years could have been effort-dependent. Annual median depth in region C ranged from 24 to 1290 m (Table 35, Figure 34). Bowheads seen in region C in 1983 were in deeper water than whales seen there in any other year (i.e., 1983 sample range did not overlap any other year's range). As a result, the median depth for 1983 (1290 m) was significantly deeper than that for any other

Table 35. Median water depth at bowhead sightings for four regions of the Alaskan Beaufort Sea, September-October 1979-86.

	(n)	MEDIAN	C.I.(99%)	RANGE
A (153°30'-157°W)				
1979			--	
1980			--	
1981			--	
1982	(6)	49	*	7-145
1983	(9)	113	5-154	5-154
1984	(22)	18	13-22	5-123
1985	(4)	41	*	7-145
1986	(7)	18	*	13-154
B (150°-153°30'W)				
1979	(10)	18	18-29	18-29
1980	(4)	20	*	(20)
1981	(3)	22	*	18-22
1982	(8)	13	9-225	9-225
1983	(9)	48	18-2122	18-2122
1984	(15)	40	18-55	11-55
1985	(3)	46	*	7-225
1986	(4)	18	*	9-51
C (146°-150°W)				
1979	(21)	29	27-35	11-40
1980	(8)	27	11-40	11-40
1981	(6)	24	*	15-40
1982	(30)	28	20-38	18-49
1983	(7)	1290	*	90-2698
1984	(9)	38	20-64	20-64
1985	(9)	29	18-38	18-38
1986	(12)	18	10-40	6-519
D (141°-146°W)				
1979	(2)	42	*	(42)
1980			--	
1981	(4)	33	*	29-46
1982	(7)	49	*	40-2799
1983	(9)	732	49-2005	49-2005
1984	(14)	36	18-62	18-466
1985	(1)	57	*	(57)
1986	(22)	30	23-40	8-56

-- = no sightings, * = insufficient sample size. All depths are given in meters.

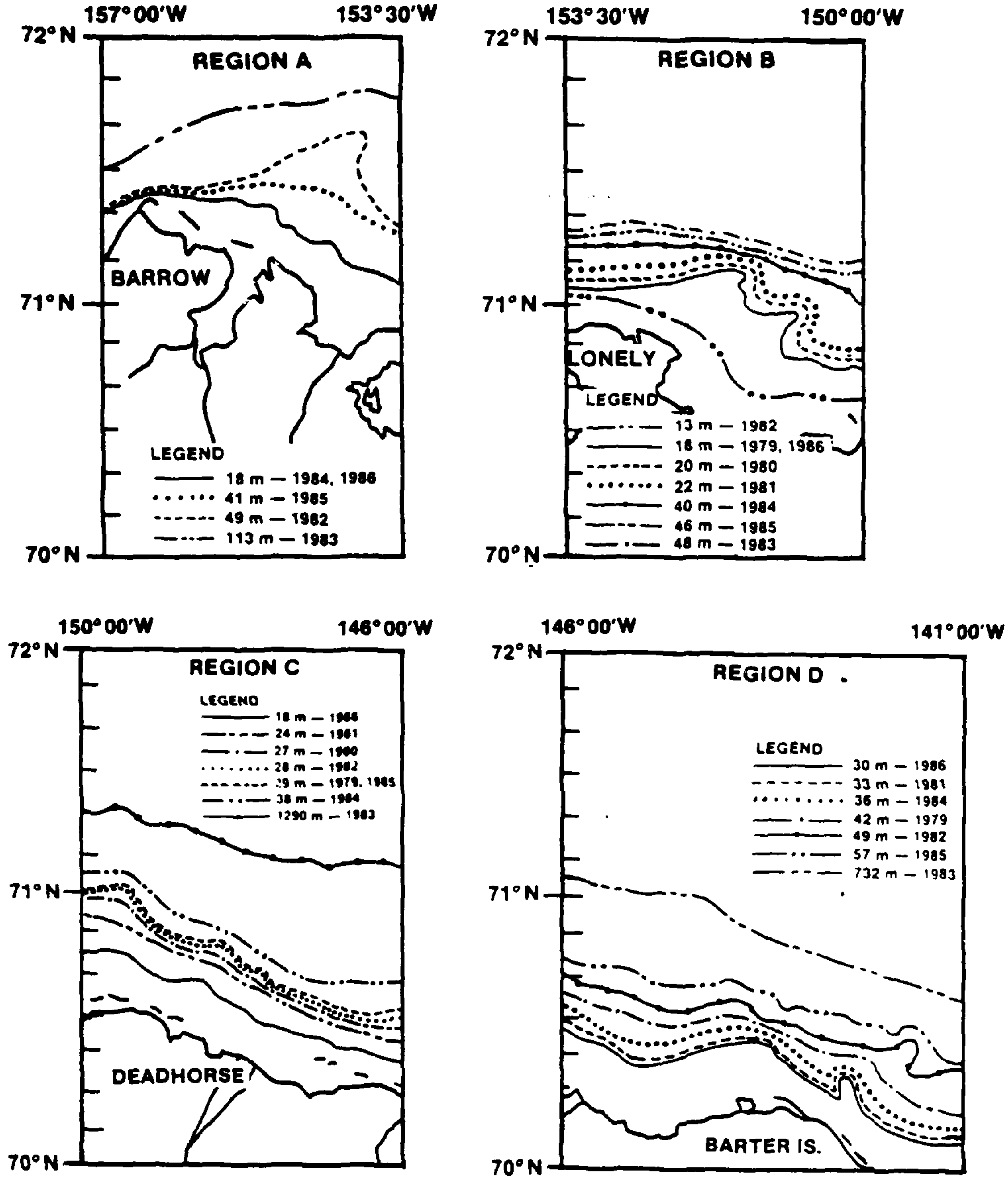


Figure 34. Annual median water depth contours depicting the bowhead migration route through four regions (A-D) of the Alaskan Beaufort Sea, September-October 1979-86.

Table 36. Results of Mann-Whitney test for comparisons of annual median water depth at bowhead sightings in the four regions of the Alaskan Beaufort Sea, September-October 1979-86.

A

	1982 (n=6)	1983 (n=9)	1984 (n=22)	1985 (n=4)
1983	U=30.5 p ≤0.50			
1984	U'=96 p ≤0.10	U'=130.5 p <0.20		
1985	U=12 p ≤0.50	U=22.5 p ≤0.50	U=45 p ≤0.50	
1986 (n=7)	U'=30 p <0.20	U=38 p ≤0.50	U'=82.5 p ≤0.50	U=16 p ≤0.50

B

	1979 (n=10)	1980 (n=4)	1981 (n=3)	1982 (n=8)	1983 (n=9)	1984 (n=15)	1985 (n=3)
1980	U'=28 p ≤0.50						
1981	U'=17.5 p ≤0.50	U'=8 p ≤0.50					
1982	U=50 p ≤0.50	U'=20 p ≤0.50	U'=15 p ≤0.50				
1983	U'=83.5 p <0.001	U=32 p ≤0.005	U=24.5 p <0.10	U=56.5 p <0.10			
1984	U=119.5 p <0.02	U=48 p ≤0.10	U=36 p <0.20	U=81.5 p <0.20	U'=91.5 p <0.20		
1985	U'=20 p ≤0.50	U'=8 p ≤0.50	U=6 p ≤0.50	U'=13.5 p ≤0.50	U=17 p ≤0.50	U'=23 p ≤0.50	
1986 (n=4)	U'=20.5 p ≤0.50	U=12 p ≤0.50	U=7.5 p ≤0.50	U=15 p ≤0.50	U=28.5 p <0.20	U=43.5 p ≤0.50	U=7 p ≤0.50

C

	1979 (n=21)	1980 (n=8)	1981 (n=6)	1982 (n=30)	1983 (n=7)	1984 (n=9)	1985 (n=9)
1980	U=96.5 p ≤0.50						
1981	U=70 p ≤0.50	U=24.5 p <0.50					
1982	U=318 p ≤0.50	U=136.5 p ≤0.50	U=111.5 p ≤0.50				
1983	U'=187 p <0.001	U'=56 p <0.002	U=42 p ≤0.002	U'=210 p <0.001			
1984	U'=127 p <0.20	U=51 p <0.20	U=41 p <0.20	U'=186.5 p <0.10	U'=63 p <0.001		
1985	U=104.5 p ≤0.50	U=39 p ≤0.50	U=30 p ≤0.50	U=159 p ≤0.50	U'=63 p <0.001	U=62 p <0.10	
1986 (n=12)	U=164 p <0.20	U=60 p ≤0.50	U'=42.5 p ≤0.50	U=245 p <0.10	U'=82 p <0.001	U'=83 p <0.05	U'=70 p ≤0.50

D

	1979 (n=2)	1981 (n=4)	1982 (n=7)	1983 (n=9)	1984 (n=14)	1985 (n=1)
1981	U'=6 p ≤0.50					
1982	U=9 p ≤0.50	U=25 p ≤0.05				
1983	U=18 p ≤0.05	U=36 p <0.005	U=44 p ≤050			
1984	U'=18 p ≤0.50	U=30.5 p ≤0.50	U'=73 p <0.10	U'=119 p <0.001		
1985	*	*	*	U=8 p ≤0.50	U'=10 p ≤0.50	
1986 (n=22)	U'=34 p <0.50	U'=64.5 p <0.20	U'=131 p ≤0.005	U'=195.5 p <0.001	U'=196 p <0.20	U'=22 p ≤0.10

year (Table 36). The only other case of significant difference in region C was that of 1984 (median depth = 38 m) and 1986 (median = 18 m). In region D, annual median depth ranged from 30 to 732 m (Table 35; Figure 34). The median depth for 1983 (732 m) was significantly deeper than 1979, 1981, 1984, and 1986 data (Table 36). There were no bowhead sightings in region D in 1980 and only one sighting in 1985.

When the 1983 data were omitted, the average median depth was deeper in region A ($\bar{x}$ = 31.50 m, 15.93 s.d., n = 4) and region D ($\bar{x}$ = 41.17 m, 10.30 s.d., n = 6), than in region B ($\bar{x}$ = 25.29, 12.53 s.d., n = 7) and region C ($\bar{x}$ = 27.57 m, 6.02 s.d., n = 7). Region D's average median depth was significantly deeper than region C's ($p < 0.02$) and region B's ($p < 0.05$), indicating that bowheads may migrate along a somewhat deeper isobath in the eastern (141°W to 146°W) Alaskan Beaufort Sea. There were no other instances of interregional differences in average median depth, indicating that the bowhead migratory corridor is roughly demarcated by the 20- to 40-meter isobath across the Alaskan Beaufort Sea west of 146°W.

b. Timing and Habitat Relationships of Migrating Bowhead Whales

Each year, considerable time has been spent describing interannual differences in the fall bowhead migration with regard to observed distribution, behavior, the timing of whale movements, and associated ice conditions. In reviewing the progress that has been achieved since 1979 in describing the migration, one factor that has remained somewhat vague is the interpretation of the term "migration", specifically as it is applied to an aerial survey assessment of its progress. Migration is defined as a seasonal or periodic (mass) movement of animals away from and back to their breeding areas, and typically precedes and follows breeding seasons. Determining annual initiation and termination dates for the bowhead migration via aerial surveys is, by nature of methodological limitations, effort-dependent. The criterion used to define the initiation of the migration since 1983 (Ljungblad et al., 1984a, 1986c) has been the sighting of one or more adult bowheads swimming in a westerly or northwesterly direction (i.e., 210° -270° M) on two separate surveys within a 5-day period. The termination of the migration has been generally defined as the date of the last bowhead sighting in the Alaskan Beaufort Sea. These criteria were subsequently applied to 1979-82 data and, coupled with annual variation in survey effort, have resulted in migratory periods of varying duration (Table 37). For example, in 1979 the initiation of the migration period was based upon sightings of three whales and one

Table 37. Summary of annual bowhead migration period, peak WPUE and date, number (percentage) of feeding bowheads, 5-day SPUE peak and SPUE peak period, average September-October ice cover, and median depth at bowhead sightings in the Alaskan Beaufort Sea, 1979-86.

	1979	1980	1981	1982	1983	1984	1985	1986
Migration Period Length (Days)	20 Aug-25 Oct (66)	4 Sep-9 Oct (35)	7 Sep-20 Oct (43)	2 Sep-17 Oct (45)	3 Sep-17 Oct (44)	7 Sep-20 Oct (44)	22 Sep 20 Oct (29)	7 Sep 17 Oct (41)
WPUE: Peak	7.33	1.25	15.75	23.60	1.86	10.73	5.23	6.01
Date	14 Oct	18 Sep	28 Sep	16 Sep	24 Sep	26 Sep	6 Oct	28 Sep
Feeding Bowheads	50(25)	5(11)	41(14)	108(22)	14(8)	148(39)	35(25)	40(26)
5-day SPUE: Peak	2.69	0.61	6.70	2.53	1.35	1.60	0.97	1.25
Period	26-30 Sept	11-15 Sept	26-30 Sept	21-25 Sept	16-20 Sept	6-10 Oct	11-15 Oct	26-30 Sept
Average Sept/Oct Ice Cover	$\leq$10%	$\geq$60%	$\leq$10%	0%	$\geq$60%	$\leq$10%	$\geq$40%	$\leq$5%
Median Depth	29 m	20 m	29 m	38 m	145 m	28 m	29 m	25 m

whale swimming in a westerly direction on 20 August and 21 August respectively. Bowheads were next seen in the Alaskan Beaufort Sea on 7 September 1979 (n = 2, swimming west), but were not seen in great numbers until aggregations ($n \geq 20$) of whales were seen near Demarcation Bay on 24 and 26 September 1979. During this period, observed behaviors included feeding and slow westerly swimming. After 26 September, whales were seen west of Demarcation Bay with most whales swimming steadily. The last whale seen in the Alaskan Beaufort Sea was on 25 October, although surveys continued through 31 October 1979. In 1980 and 1981, very few surveys were conducted in the Alaskan Beaufort Sea prior to the migration initiation date in early September, so potential whale distribution and movements in August could not be fully described. Since 1982, surveys have been initiated in the Alaskan Beaufort Sea in August, and have extended offshore to 72°N. In 1982 and 1983, westerly swimming bowheads were seen in the Alaskan Beaufort Sea as early as 5 August and 2 August respectively. Because these whales were primarily offshore (see Figure 31) and in deep water, it was determined by the NMFS that they would not likely be affected by current near-shore OCS oil and gas activities and, therefore, these sightings were not incorporated in the defined

nearshore migratory period. In 1984-86, most of the bowheads seen in August were relatively near shore in shallow water, as in 1979, but these whales were not swimming west. Therefore, initiations of the 1984-86 bowhead migrations were in September. Determining the migration termination date was also affected by annual variations in the level and direction of survey effort. The termination of the migration in 1986 was 17 October, when the last bowhead was seen in the Beaufort Sea. No bowheads were seen during a later survey, even though significant open water areas still existed in the central Alaskan Beaufort. In 1980, nine surveys were flown in the Alaskan Beaufort Sea after the migration termination date. Since 1981, zero to five surveys have been conducted after the last whale sighting. In 1985, the termination of the migration was based upon efforts of three aircraft resulting in no bowhead sightings on two consecutive days. Resultant migratory periods have ranged from 35 to 66 days (Table 37). The 1985 bowhead migration extended from 22 September to 20 October, a shorter time period (29 days) than any previous year.

The timing of the observed fall bowhead migration described as the sightings per unit effort (SPUE = no. sightings/hour of survey effort) per 5-day time period minimizes bias introduced when the number of whales are used (Figure 35). Sighting rates in August (1979-81) and the latter part of October reflect partial cover during those time periods. Since 1979, the peak 5-day sighting period has occurred between 11-15 September and 11-15 October (Table 37, Figure 35). Peak 5-day SPUE periods were earlier in years of heavy-ice cover (1980: 11-15 September; 1983: 16-20 September) than in years when ice was light (Table 37). Peak 5-day sighting rate was highest in 1981 (SPUE = 6.70) when most September surveys were dedicated to observing bowhead behavior near active geophysical vessels (Fraker et al., 1985).

To analyze the interrelationship of migratory timing, behavioral parameters and habitat relationships as described by average annual September-October ice cover and median depth, a multiple regression was performed on the data summarized in Table 37. The initiation of the migration was defined as the dependent variable (Y), and peak WPUE, percentage of feeding whales, 5-day SPUE peak, SPUE peak period, percentage of ice, and median depth constituted the independent variables ($x_1 .... x_6$). The resultant correlation coefficients are summarized in Table 38. The strongest relationship was the negative correlation of ice cover with peak WPUE ($r = -0.746$, $p < 0.05$). Ice cover was also negatively

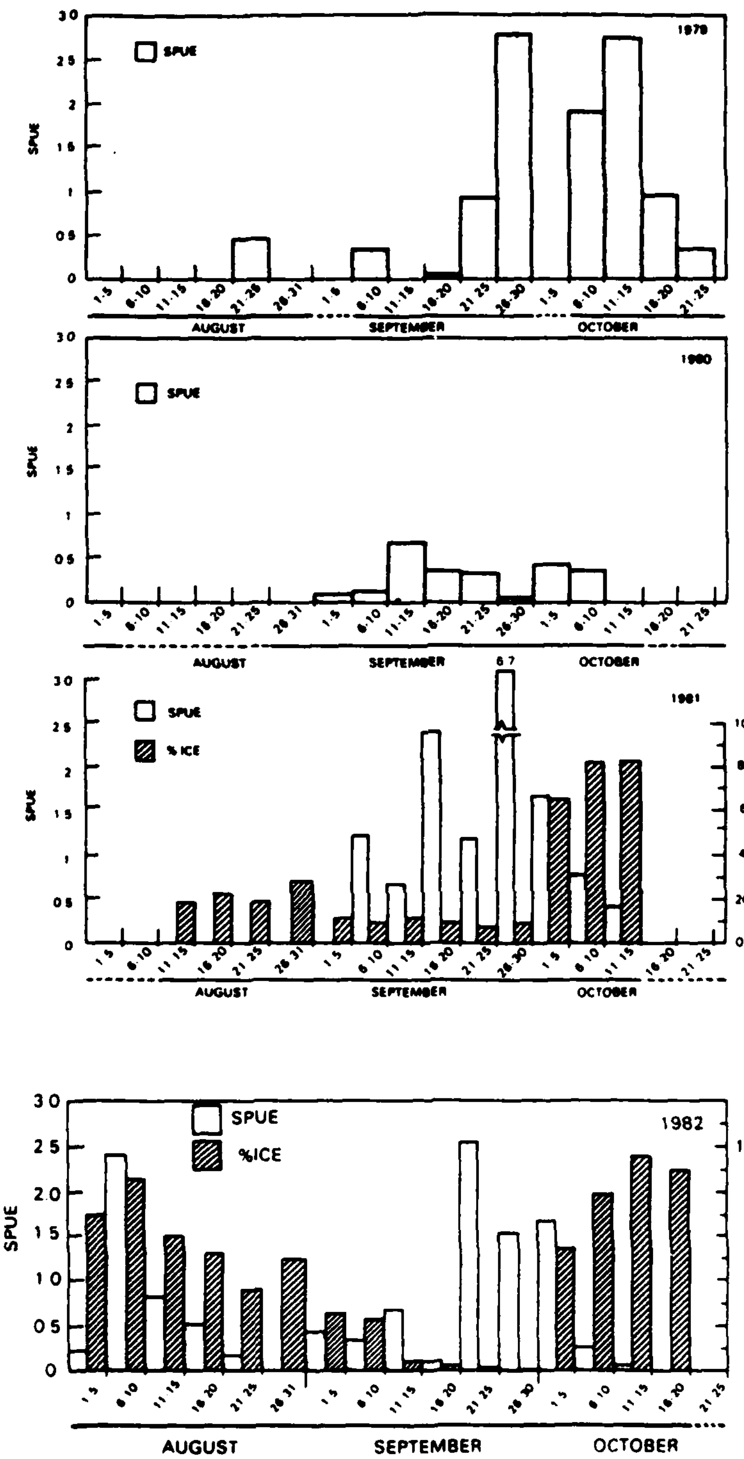


Figure 35. Bowhead sightings per unit effort (SPUE = no sightings/hours of survey effort), and percentage of ice cover, 1979-86. Ice cover was not routinely recorded in 1979 and 1980, and therefore not incorporated in this analysis. A solid line (—) appears under periods of survey coverage; a dotted line (---) indicates periods without survey coverage.

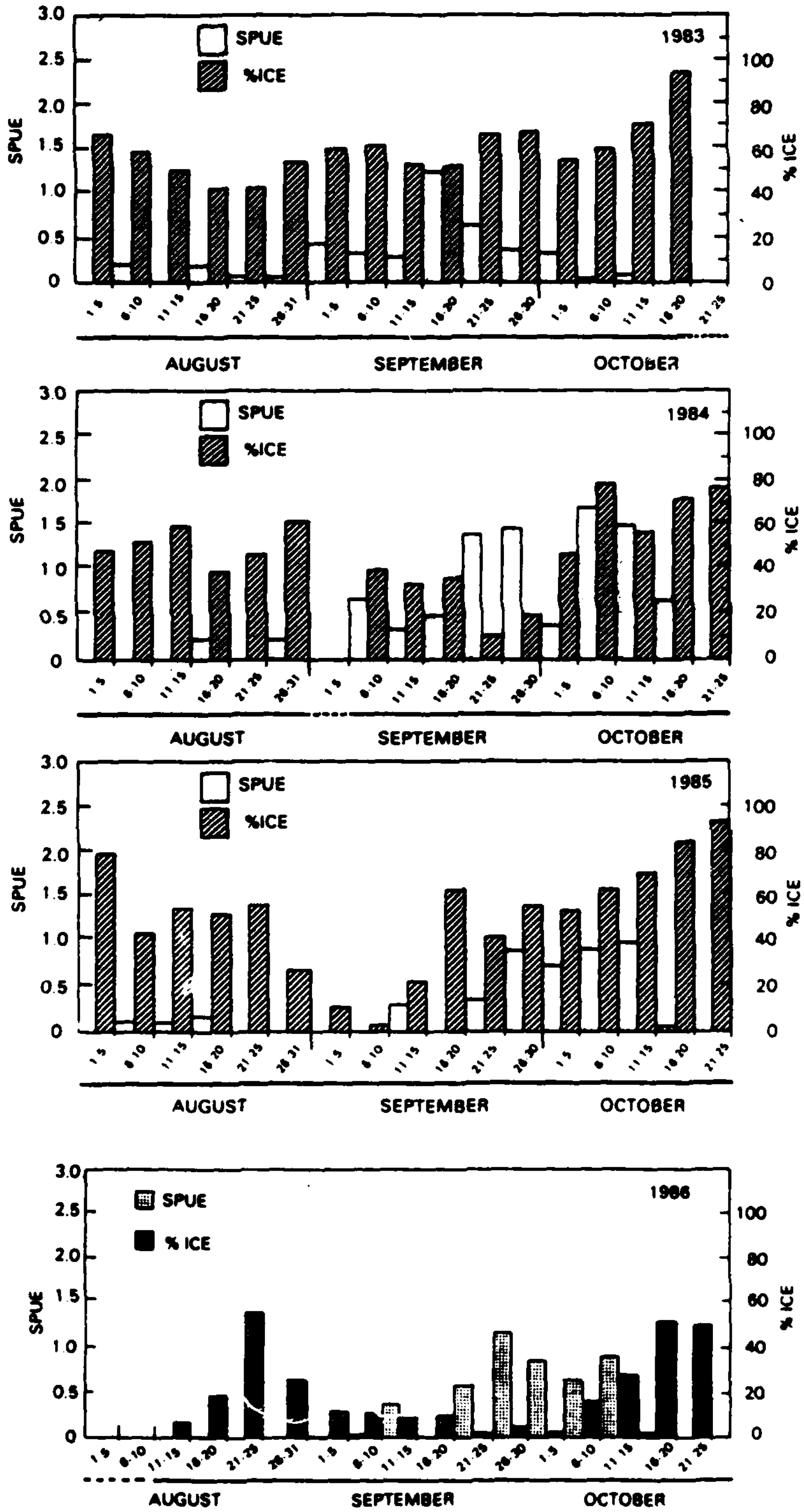


Figure 35 (contd).

Table 38. Matrix of correlation coefficients relating the migration initiation date (Y) to WPUE Peak (x_1), % feeding whales (x_2), SPUE peak (x_3), SPUE peak period (x_4), % ice cover (x_5), and median depth (x_6).

	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(Y)
Peak WPUE	1.0						
% Feeding	0.250	1.0					
Peak SPUE	0.575 1)	-0.167	1.0				
SPUE Period	0.202 2)	0.731 3)	0.143	1.0			
% Ice	-0.746 3)	-0.625 2)	-0.625	-0.466	-0.490	1.0	
Median Depth	-0.279	0.507 1)	0.138	-0.373	0.507 1)	1.0	
MIG. Initiation	-0.101	0.109	-0.167	0.459	0.231	-0.10	1.0

1) $p < 0.20$
2) $p < 0.10$
3) $p < 0.05$

associated with the percentage of feeding whales ($r = -0.625$, $p < 0.10$). Because group size of feeding whales is significantly larger than that of non-feeding bowheads (Ljungblad et al., 1986a), the calculated WPUE is strongly influenced by the observed number of feeding whales. Therefore, it is not surprising that both WPUE and the percentage of feeding whales are negatively associated with heavy-ice cover, as ice cover curtails productivity and in this way may limit bowhead feeding opportunities. The percentage of feeding whales was positively associated with peak SPUE period ($r = 0.731$, $p < 0.05$), indicating that in years of lighter ice when more whales are feeding, peak SPUE will be later than in heavy-ice years when few whales are feeding. The annual median depth defining the axis of the bowhead migration was negatively associated with all parameters except ice cover, although none of the relationships were significant (Table 38). The positive association of median depth with ice cover may indicate that in heavy-ice years, such as 1983, the migration proceeds farther offshore in deeper water than in light-ice years. This may have indeed been the case in 1980, however, as surveys were conducted only in relatively nearshore shallow water that year and whales migrating farther offshore in deeper water may have been missed.

The route, timing, and character of the fall bowhead migration across the Alaskan Beaufort Sea appears to be related to bowhead feeding opportunities, and

secondarily to the extent of ice cover and its effect on migratory route and prey productivity. Ice cover limits primary and, therefore, secondary productivity (i.e., bowhead food) by deflecting and diffusing incident light (Schell et al., 1982). The trend, described for 7 years of data, was for migrations in light-ice years (1979, 1981-82, 1984) to be longer, result in a higher and later WPUE, and with more feeding whales than migrating whales in heavy-ice years (1980, 1983); the ice conditions encountered in 1985 have been described as intermediate (Ljungblad et al., 1986b). The 1986 migration did not conform completely to this scenario. The migration was relatively short (41 days), and supported relatively low WPUE (6.01) and 5-day WPUE (1.25) values. The timing and general character of the 1986 migration was most similar to that observed in 1981 when SPUE was relatively high from 26-30 September, with peak WPUE on 28 September. The influence of ice cover on the fall migration may be indirectly related to the effects of ice cover on prey productivity along the ice front and/or as a limitor to incident light. Understanding the specific effects of ice cover on prey productivity in areas where bowheads have been seen feeding, and in areas where they may feed such as the ice front, may better explain the impact of ice conditions on migratory dynamics.

In general, bowheads were seen each year most often in whatever ice cover predominated during the latter half of September or first half of October when the majority of migrating whales were observed. Since 1981, 67 percent (n = 1094) of all bowheads seen were in open water (i.e., ice cover < 10%; Table 39). Eighty-five whales (5%) were in light (11-30%) ice cover, 116 whales (7%) were in medium (31-60%) ice cover, and 332 whales (21%) were in relatively heavy ($\geq$60%) ice cover. These data were not corrected for the potential effects ice cover may have on the ability of observers to sight surfaced whales.

c. Observed Migration Patterns in the Northeastern Chukchi Sea

Over 166 hours of survey effort has been conducted in blocks 13 through 18 in the northeastern Chukchi Sea since 1979 (Table 31). Most of the effort (98%, 162.7 hrs) has been conducted since 1982 when transect surveys in the Chukchi Sea were initiated. Since 1982, 51 bowheads have been seen (WPUE = 0.31), with annual abundance indices (WPUE) of 0.91 in 1982, 0.79 in 1983, 0.26 in 1984, 0.20 in 1985, and 0.05 in 1986. Most whales were seen in block 13 (76%, n = 39), with fewer sightings in block 17 (12%, n = 6), block 14 (8%, n = 4), and block 18 (4%, n = 2). Survey block abundance indices (WPUE) ranged from 0.53 to 0.13 (Table 31).

Table 39. Number (No.) and percent (%) of bowheads found in each ice cover class, fall 1981-86.

Ice Cover (%)	1981 No.(%)	1982 No.(%)	1983 No.(%)	1984 No.(%)	1985 No.(%)	1986 No.(%)	Total No.(%)
0-10	234(81)	309(63)	46(27)	282(74)	68(49)	155(98)	1094(67)
11-20	9(3)	6(1)	0(0)	11(3)	1(1)	0	27(2)
21-30	5(2)	8(2)	22(13)	4(1)	19(14)	0	58(3)
31-40	1(0.5)	12(12)	13(8)	19(5)	3(2)	0	48(3)
41-50	10(3)	6(1)	4(2)	16(4)	0(0)	2(1)	38(2)
51-60	1(0.5)	13(3)	12(7)	4(1)	0(0)	0	30(2)
61-70	6(2)	29(6)	27(16)	1(0)	1(1)	0	64(4)
71-80	19(7)	30(6)	23(13)	7(2)	29(21)	1(1)	109(6)
81-90	3(1)	75(15)	25(14)	25(7)	5(3)	0	133(9)
91-100	0(0)	2(1)	0(0)	11(3)	13(9)	0	26(2)
TOTAL	288(100)	490(100)	172(100)	380(100)	139(100)	158(100)	1627(100)

Ice cover was not routinely recorded in 1979-80.

Bowheads have been seen in the northeastern Chukchi from 22 September through 22 October between Pt. Barrow and approximately 70 km northwest of Icy Cape (Figure 36A). Swimming direction was significantly clustered around a mean heading of 250°T (Figure 36B). This southwestward heading indicates that at least some bowheads disperse across the Chukchi Sea crossing roughly over Herald Shoal (70°30'N, 171°30'W) enroute to the Chukotka peninsula and ultimately the northern Bering Sea (reviewed by Ljungblad et al., 1986). The number of bowheads migrating across the Chukchi Sea south of Barrow probably varies from year to year, but the reasons for the variation are not immediately clear. For example, the annual abundance indices for 1982-83 were over three times larger than for 1984-85, and 15 times larger than the WPUE for 1986. As previously described, the ice edge in 1986 was farther offshore than for any prior study year. Braham et al. (1980) suggest that bowheads travel primarily along the ice front west to Herald and Wrangel Islands before following the Chukotka peninsula south and through the Bering Strait. This may have been the route taken by most whales in 1986. The annual abundance indices for 1982-83, and to a lesser extent 1984-85, indicate that

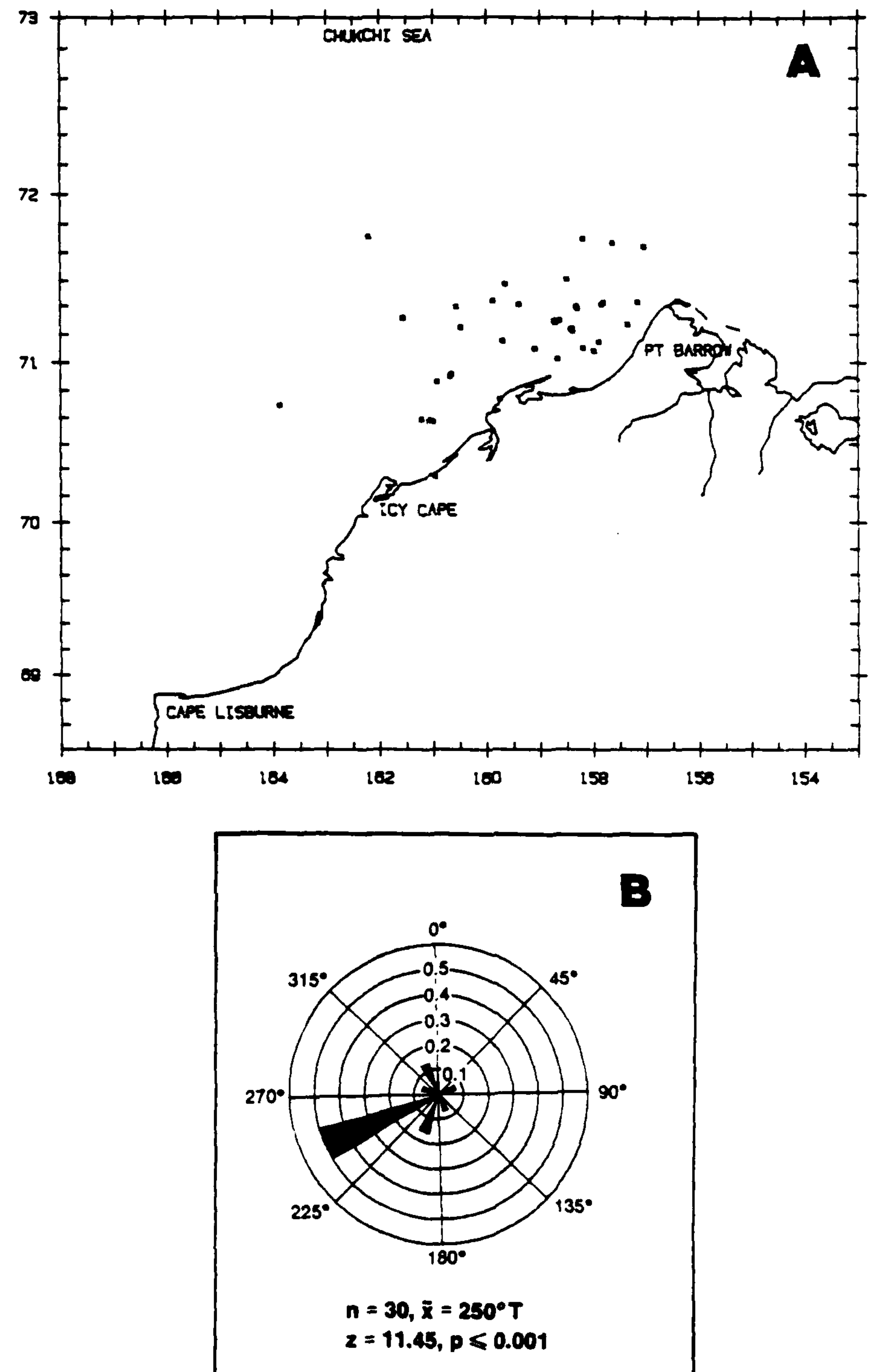


Figure 36. Distribution of 37 sightings of 51 bowheads, and analysis of swimming direction in the northeastern Chukchi Sea, 1982-86.

this route may not be strictly adhered to every year, however. Between 1982-85, relative abundance (WPUE) in block 13 was roughly similar to that calculated for blocks 3, 6 and 7 in the Alaskan Beaufort Sea (Table 31). This data, coupled with the significant southwesterly swimming direction, indicate that at least some portion of the bowhead population often disperses across the Chukchi Sea, while other whales likely take a more northerly route across to Wrangel Island before encountering the Chukotka coast.

Bowheads seen in the Chukchi Sea were usually swimming and diving (69%, n = 35). Nine whales (18%) were seen feeding in block 13, and one cow-calf pair was seen in block 18 in mid-October 1983 (Moore et al., 1986). Three whales (6%) were tail slapping and breaching and two whales (4%) were resting.

Probability of Detecting Bowhead Whales During the Fall Migration

The inability of observers to detect whales during aerial surveys will obviously affect distribution, relative abundance, density, migratory route, and timing results. Bowheads are missed by aerial observers either because (a) they are at the surface but go undetected, or (b) they are submerged as the aircraft passes over their location. The sightability of surfaced whales is affected by observer ability and by surface conditions (i.e., sea state and ice cover). The relative ability of each observer to detect surfaced whales will vary with visual acuity, attention span, the ability to withstand fatigue, experience with aerial surveys, and seat position or type of window. These factors have not been documented for each observer during bowhead aerial surveys, but have been described as having a significant ($p < 0.03$) effect on the outcome of other marine mammal surveys (Leatherwood et al., 1978). Magnusson et al. (1978) described an analysis, mathematically similar to mark-recapture techniques, that provides an estimate of the proportion of whales at the surface that are missed by observers. This method requires three full-time observers, such that two observers can survey independently from the same side of the aircraft. Because aerial surveys for bowheads in the Alaskan Beaufort Sea have not been conducted in this manner, the best approximation of surfaced whales missed by observers may be that derived for aerial surveys of bowheads in the Canadian Beaufort Sea (Davis et al., 1982). The analysis performed by these researchers indicated that the raw bowhead count by a single observer on one side of the aircraft could be corrected for unseen surfaced whales by dividing that count by $0.685 \pm$ s.e. 0.177. Because this correction

Table 40. Correlation coefficients relating the effects of ice cover and sea state surface conditions to the perpendicular sighting distance of bowheads from the survey track line.

Year	Ice Cover (%)	Sea State
1981 (n = 24)	r = 0.268, p <0.50	r = -0.380, p <0.10
1982 (n = 172)	r = -0.299, p <0.001	r = -0.009, p <0.50
1983 (n = 62)	r = -0.260, p <0.05	r = -0.041, p >0.50
1984 (n = 89)	r = -0.156, p <0.20	r = -0.082, p <0.50
1985 (n = 33)	r = 0.023, p >0.50	r = -0.266, p <0.20
1986 (n = 77)	r = -0.082, p <0.50	r = 0.120, p <0.50
1981-86 (n = 457)	r = -0.174, p <0.001	r = -0.051, p <0.50

factor applies to sightings, it is potentially biased if large groups of whales are more easily detected than small groups or individuals, and it does not include any correction for submerged whales.

The effect of surface conditions on the sightability of surfaced whales was analyzed by comparing the perpendicular sighting distance of whales from the survey track line (see Figure B-1) to the percentage of ice cover and sea state at the sighting. All sightings that had a perpendicular sighting distance (i.e., for which a clinometer angle was recorded) were entered into the analysis, regardless of whether the whales were seen during search or line transect surveys. Ice cover and sea state were not routinely recorded at bowhead sightings in 1979 and 1980, thus, the analysis was performed on 1981-86 data only. Annual correlation coefficients (Table 40) indicated that in 1981, 1984, 1985, and 1986 ice cover did not have a significant effect on sighting distance, but that sighting distance was significantly affected by ice cover in 1982 ($r = -0.299$, $p < 0.001$) and in 1983 ($r = -0.260$, $p < 0.05$). Ice conditions in the Alaskan Beaufort Sea in 1982 were much lighter than those in 1983, so it is unlikely that similarities in survey conditions affected the results of the annual regressions. Sea state was negatively associated with sighting distance in all years except 1986, but these correlations were not statistically significant. When 1981-86 data were pooled, sighting distance was significantly negatively correlated with ice cover ($r = -0.174$, $p < 0.001$) and negatively associated with sea state ($r = -0.051$, $p < 0.50$)

Because the intercorrelation of ice cover and sea state for the pooled sample was strong ($r = 0.476$, $p < 0.001$), it is not appropriate to describe a precise regression function using these regression coefficients (Zar, 1984: Section 20.4).

Because the pooled data indicates that ice cover negatively affects the sightability of surfaced whales, the 0.685 correction factor derived by Davis et al. (1982) may be enhanced if paired comparisons of individual sighting rates could be completed with regard to different ice conditions. Ideally, the results of such a comparison would be the derivation of a series of correction factors weighted by the percentage of extant ice cover. For example, Davis et al. (1982) noted that the probability of detecting surfaced whales in areas of "extensive pan ice" (i.e., $\geq$ 70% coverage) is high because an observer's attention can be focused for a "considerable period" on the relatively small, generally calm open water areas. Conversely, ice cover of 30 to 70% may inhibit an observer's search pattern and not be sufficient to appreciably dampen high sea states, while calm water with light-ice conditions (i.e., $\leq$30%) may facilitate an observer's search. In the absence of paired tests of sighting rates in a variety of ice conditions, 0.685 remains the best correction estimate for surfaced bowheads that are not detected by any individual observer.

Bowheads spend most of the time underwater. The probability that a whale will be at the surface when its location first comes into visual range may be described as

$$\frac{s}{s+u} + \frac{t}{s+u} = \frac{s+t}{s+u}$$

where s is the duration of surfacing, u is the duration of dives, and t is the duration of potential detectability (Eberhardt, 1978). Because only bowheads within 1 km of the survey track line have been considered when calculating bowhead density (see Appendix B), the parameter t was calculated as the time taken to travel 1 km at an average survey speed of 240 km/h; (i.e., $t = 0.25$ min.). Although the 0.25-minute figure seems a reasonable average estimate of duration of potential detectability, variation in survey speed, the potential detection of subsurface bowheads, or the detection of whales after the aircraft has passed their location will all affect the t estimate.

The dive and surface profiles of bowhead whales in the Alaskan Beaufort Sea were measured each fall 1981-84 during the course of surveys conducted to assess the effects of geophysical exploration on whale behavior (Fraker et al., 1985;

Reeves et al., 1983; Ljungblad et al., 1984b; Ljungblad et al., 1986c). Most whales for which respiratory data were collected during these studies were either milling or feeding, not migrating. Based on the four sets of data, the proportion of time noncalf bowheads remained at the surface ranged from 11% to 18.5%, with an overall average of 13.6% (Table 41). The corresponding detection probabilities were calculated as 0.133 to 0.219, with a 0.160 overall average. Surface and dive times were reported for shallow (< 27-30 m) and relatively deep (30-50 m) water in 1982-84. The proportion of time that bowheads in shallow water remained at the surface ranged from 10.3% to 16.3% with a 12.2% 3-year average. Corresponding detection probabilities for whales in shallow water ranged from 0.127 to 0.194, with a 0.151 average. The proportion of time that whales in deeper water remained at the surface ranged from 12.5% to 22.7%, with 15.8% average for the two years for which data were available. Detection probabilities for whales in 30-59 m deep water ranged from 0.142 to 0.267, with a 2-year 0.181 average. Although the proportion of surface time for whales in 30- 50-m deep water was longer than for whales in shallower water, these differences were not significant ($X^2 = 0.050$, $p < 0.90$).

The results presented in Table 41 indicate that bowheads in the Alaskan Beaufort Sea were at the surface 13.6% of the time, and that 16% of the whales within 1 km of a random transect survey leg would be expected to be detectable. Since 1979, an annual average of 124 bowheads have been seen within 1 kilometer of the aircraft on random transect surveys that cover an average 65% of the study area. When corrected for 100% of the survey area (n = 191), and for surfaced whales that are missed by aerial observers (i.e., 191/0.685), this number represents 279 whales. If these 279 whales comprise the component of whales at the surface as the aircraft passes over (i.e., 16%), then on average 1744 whales are actually represented by the annual average of 124 bowheads seen on transect.

Behavior and Sound Production

The proportion of bowhead behaviors observed in 1986 was roughly similar to previous years (Table 42). Migratory behaviors (swimming and diving; see Table 3) comprised 58 percent of all behaviors seen, a lower proportion than in all years except 1982 and 1984-1985. Forty-two percent of all whales seen in 1986 were socializing. These proportions were most like those seen in 1979. There were no clear trends in the year-to-year variation of migratory and social behavior proportions.

Table 41. Calculation of the probability that a bowhead whale will be at the surface and within an observer's field of view while conducting a random ansect line.

	SURFACE TIME(S) $\bar{x}$	SURFACE TIME(S) s.d.	SURFACE TIME(S) n	DIVE TIME(U) $\bar{x}$	DIVE TIME(U) s.d.	DIVE TIME(U) n	Prop. of Time at surface	Detection Probability $\frac{S+.25}{S+U}$
A. September 1981								
Non-calves	1.82	0.94	42	13.31	6.81	20	12.0%	0.137
B. September 1982								
Non-calves	1.36	0.59	31	5.98	3.02	6	18.5%	0.219
Water depth								
<27.45 m	1.33	0.67	42	6.83	4.07	19	16.3%	0.194
>27.45 m	1.77	0.81	48	-	-	1	-	-
C. September 1983								
Non-calves	1.33	1.10	168	7.11	5.94	59	15.8%	0.187
Water depth								
< 30 m	1.04	0.63	88	9.08	6.66	27	10.3%	0.127
30-59 m	1.42	0.87	35	4.84	4.86	14	22.7%	0.267
D. September 1984								
Non-calves	1.19	0.87	155	9.61	8.14	30	11.0%	0.133
Water depth								
< 30 m	0.82	0.57	100	6.90	7.09	17	10.6%	0.139
30-59 m	1.88	0.90	55	13.16	8.32	13	12.5%	0.142
OVERALL AVERAGE								
Non-calves	1.42	0.24	4	9.00	2.81	4	13.6%	0.160
Water depth								
27-30 m	1.06	0.21	[illegible]	7.60	1.04	3	12.2%	0.151
30-59 m	1.69	0.20	[illegible]	9.00	4.16	2	15.8%	0.181

A. Fra[illegible]er et al., 1985: Table 3
B. Reeves et al., 1983: Table 9
C. Ljungblad et al., 1984b: Table 11
D. Ljungblad et al., 1985b: Table 1

Table 42. Proportions of migratory and social bowhead behaviors, 1979-86.

	1979	1980	1981	1982	1983	1984	1985	1986
Migratory	59	85	64	44	62	37	44	58
Social	41	15	36	56	38	63	56	42

Fifty-four percent of all whales seen in 1986 were swimming, a greater proportion than in all years except 1983 (55%; Table 43). Feeding whales accounted for 26 percent of the total, similar to that of the 8-year average. Only 1 percent of all whales seen in 1986 were milling, and 4 percent each were seen diving and resting. Cow-calf association represented 5 percent of all observations, a proportion lower than in 1983 and 1985 but higher than in all other years. Six percent of all behaviors seen in 1986 were displays, higher than in all other years except 1983 (14%).

Bowhead swimming direction in the Beaufort Sea from 1-15 August 1982-86 was significantly clustered around a mean heading of 310°T ($n = 58$, $z = 4.35$, $p < 0.01$) (Figure 37). This overall value, however, was strongly influenced by bowhead swim direction in early August 1982 ($\bar{x} = 315°T$, $n = 40$, $z = 5.03$, $p < 0.01$), since bowhead swim direction in 1-15 August 1983-85 (no surveys were flown 1-15 August 1986) was not significantly clustered around any mean heading. Bowheads seen in early August 1982 may have been part of an early offshore migration (Ljungblad et al., 1983).

Whales maintained headings in all direction during the latter half of August and early September 1982-86 (Figure 37). Swim direction was significantly clustered around a mean heading of 280°T ($p < 0.001$) in late September. The westerly heading was maintained through early (284°T, $p < 0.001$) and late (277°T, $p < 0.01$) October.

The call rate derived for 1986 was higher than for any previous fall (Table 44). This is likely an artifact of the small acoustic sampling effort conducted from the survey aircraft in 1986 when bioacoustic efforts were largely directed toward sampling at the Barter Island acoustic station. The high call rate in 1986 is not necessarily atypical for the season, however, as bowhead call rate in fall was found to be significantly ($p < 0.005$) higher than spring or summer call rates (Ljungblad et al., 1986b).

Table 43. Semimonthly summary of bowhead behavior, 1979-86.

Behavior	Year	1-15 Aug	16-31 Aug	1-15 Sep	16-30 Sep	1-23 Oct	Total (%)
Swim	1979	--	4	2	6	57	69 (50)
	1980	--	--	7	5	2	14 (31)
	1981	--	2	38	70	19	129 (51)
	1982	64	7	5	77	29	182 (37.5)
	1983	27	8	6	37	16	94 (55)
	1984	2	8	13	46	60	129 (34)
	1985	5	3	3	17	30	58 (42)
	1986	1	5	24	28	28	86 (54)
	Total	**99**	**37**	**98**	**286**	**241**	**761 (43)**
Dive	1979	--	3	0	3	7	13 (9)
	1980	--	--	0	17	8	25 (54)
	1981	--	0	5	20	8	33 (13)
	1982	5	3	4	16	3	31 (6.5)
	1983	2	0	4	5	1	12 (7)
	1984	0	0	4	2	6	12 (3)
	1985	0	0	0	2	1	3 (2)
	1986	--	2	3	1	--	6 (4)
	Total	**7**	**8**	**20**	**66**	**34**	**135 (8)**
Rest	1979	--	0	0	0	2	2 (1)
	1980	--	--	0	0	0	0 (0)
	1981	--	0	17	22	6	45 (18)
	1982	18	7	2	5	8	40 (8)
	1983	8	0	3	1	0	12 (7)
	1984	1	1	0	7	15	24 (6)
	1985	2	0	2	5	6	15 (11)
	1986	2	1	--	3	1	7 (4)
	Total	**31**	**9**	**24**	**43**	**38**	**145 (8)**
Feed	1979	--	0	0	43	7	50 (36)
	1980	--	--	5	0	0	5 (11)
	1981	--	0	8	22	11	41 (16)
	1982	0	0	23	85	0	108 (22)
	1983	4	0	0	0	10	14 (8)
	1984	0	8	0	138	2	148 (39)
	1985	0	0	23	0	12	35 (25)
	1986	8	20	10	2	--	40 (26)
	Total	**12**	**28**	**69**	**290**	**42**	**441 (25)**
Mill	1982	12	12	7	50	0	81 (17)
	1984	0	0	0	46	0	46 (12)
	1985	0	0	6	2	1	9 (6)
	1986	--	1	1	--	--	2 (1)
	Total	**12**	**13**	**14**	**98**	**1**	**138 (8)**
Cow-Calf	1979	--	0	0	0	4	4 (3)
	1980	--	--	0	0	2	2 (4)
	1981	--	0	0	2	2	4 (2)
	1982	8	6	6	0	2	22 (4.5)
	1983	0	2	4	4	6	16 (9)
	1984	0	0	0	4	6	10 (3)
	1985	0	0	0	6	6	12 (9)
	1986	--	--	--	2	6	8 (5)
	Total	**8**	**8**	**10**	**18**	**34**	**78 (4)**
Display	1979	--	0	0	0	1	1 (1)
	1980	--	--	0	0	0	0 (0)
	1981	--	0	0	0	0	0 (0)
	1982	0	2	7	12	1	22 (4.5)
	1983	8	0	7	7	2	24 (14)
	1984	0	1	0	0	10	11 (3)
	1985	2	0	0	1	4	7 (5)
	1986	1	0	2	3	3	9 (6)
	Total	**11**	**3**	**16**	**23**	**21**	**74 (4)**
*Total	1979	--	7	2	52	78	139*
	1980	--	--	12	22	12	46
	1981	--	2	68	136	46	252*
	1982	107	37	54	245	43	486*
	1983	49	10	24	54	35	172
	1984	3	18	17	243	99	380
	1985	9	3	34	33	60	139
	1986	12	29	40	39	38	158
	Total	**180**	**106**	**251**	**824**	**411**	**1772 (100)**

*Behavior was not recorded for 98 whales: 58 in 1979; 36 in 1981; and 4 in 1982. (--) = no sightings.

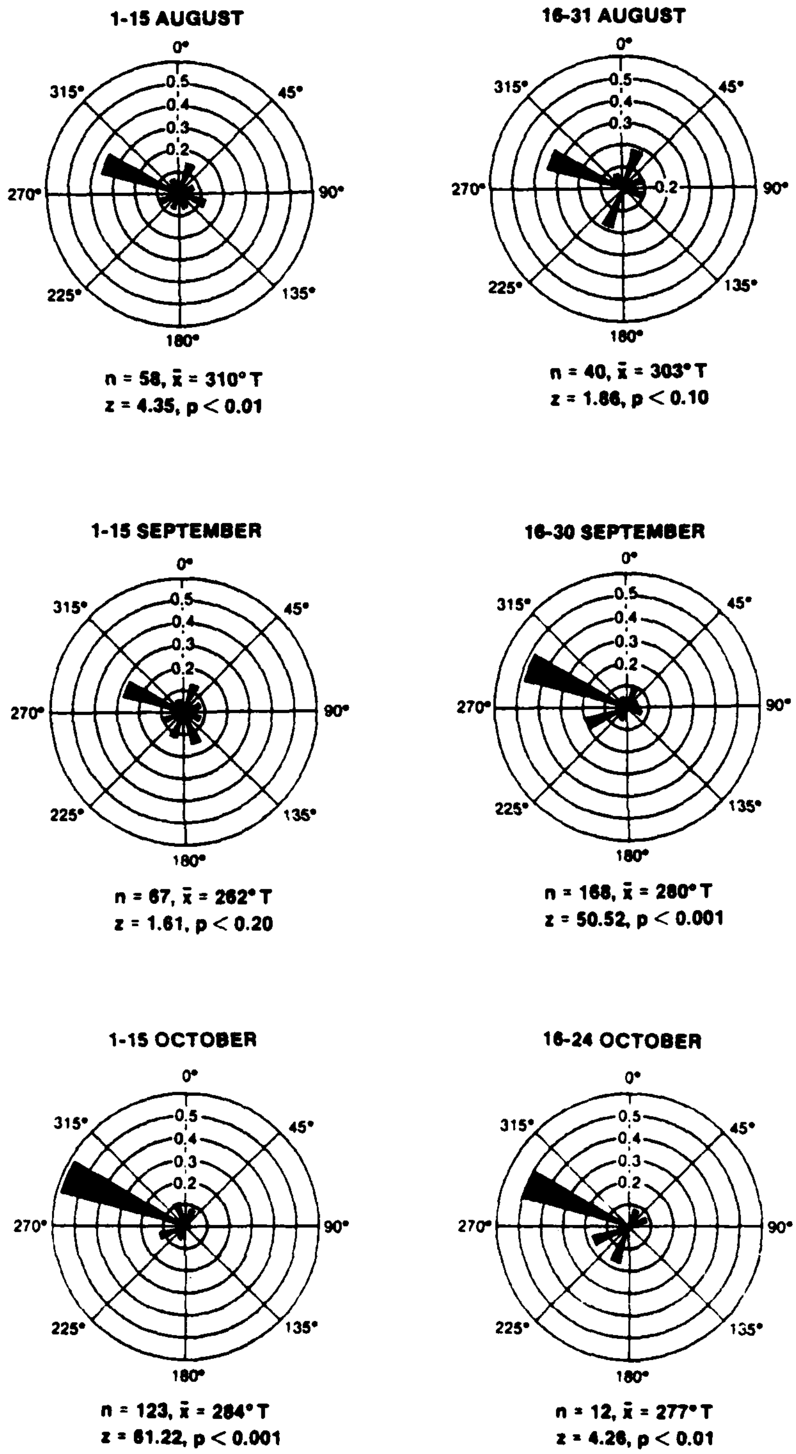


Figure 37. Bowhead swimming direction in the Alaskan Beaufort Sea, 1982-86.

Table 44. Percent of bowhead calls of each category, recorded from aircraft-deployed sonobuoys, 1982-86.

	CALL TYPE								
	Simple				Complex				
Year	Call Rate	Up %	Down %	Const. %	Inflect %	High %	Growl %	Trumpet %	No. Calls
1982	0.9	20	27	8	17	8	10	10	2012
1983	11.3	32	15	7	18	2	22	4	1194
1984	1.1	21	17	1	23	3	19	16	182
1985	1.9	19	25	3	11	3	35	4	170
1986	15.6	14	14	2	0	0	70	0	70

All bowhead call types recorded during the falls of 1982-86 were qualitatively very similar to those recorded and quantitatively described for the spring migration (Ljungblad et al., 1982; Clark and Johnson, 1984), and the relative proportions of simple and complex calls were roughly similar each year (Table 44). Simple FM calls comprised 30 to 80 percent of the bowhead fall call sample with a 5-year average of 62 percent; conversely, 20 to 70 percent of bowhead calls recorded in fall were complex AM signals with a 38 percent 4-year average. This 5-year fall proportion of simple/complex calls (62/38) contrasts with 2-year spring (52/48; Moore et al., 1984) and 5-year summer (87.5/12.5; Würsig et al., 1985) proportions, indicating there may be some seasonal differences to the call types produced. The interpretation of these differences is compromised in several ways. Although the procedures for call categorization have been agreed upon by the different analysts, call samples have largely been reviewed and counted aurally, resulting in an inherent reliance on the listener's hearing and subjective judgement. The time and cost of analyzing all recorded sounds via spectral processes have, to date, been prohibitive. Therefore, there is probably some subjective bias to the proportion of calls reported. Secondly, and perhaps more important, are the circumstances (i.e., environmental conditions and/or researcher's motivation) involved in recording data. In spring and fall, sonobuoys were usually dropped near groups of whales, and occasionally, when whales were not seen, to acoustically monitor an area for whale presence. In

Table 45. Number and abundance indices (CPUE = no. calves/hours of survey effort) of bowhead calves by block, 1979-86.

	August		September		October		Total	
Block	No. Calves	CPUE	No. Calves	CPUE	No. Calves	CPUE	No. Calves	CPUE
1	0	-	2	0.01	9	0.06	11	0.03
2	0	-	2	0.07	0	-	2	0.03
3	0	-	1	0.01	5	0.06	6	0.03
4	0	-	5	0.06	0	-	5	0.03
5	**8**	**0.10**	**9**	**0.10**	0	-	**17**	**0.09**
6	3	0.06	2	0.04	0	-	5	0.05
7	4	0.08	1	0.03	**2**	**0.36**	7	0.08
8	0	-	0	-	0	-	0	-
9	0	-	1	0.08	0	-	1	0.04
10	0	-	0	-	0	-	0	-
11	0	-	1	0.04	3	0.11	4	0.07
12	0	-	0	-	3	0.04	3	0.03
13	0	-	0	-	1	0.02	1	0.01
14	0	-	0	-	0	-	0	-
15	0	-	0	-	0	-	0	-
16	0	-	0	-	0	-	0	-
17	0	-	0	-	0	-	0	-
18	0	-	0	-	1	0.08	1	0.06
Canada	2	0.20	1	0.05	0	-	3	0.08
Total	17	0.04	25	0.04	24	0.04	66	0.04

Bold indicates peak CPUE.

summer, sonobuoys were always dropped near whales (Würsig et al., 1985). Although statistically significant correlations between observed behaviors and call production have not been demonstrated for bowheads, general trends of socializing whales producing higher proportions of complex calls and swimming or resting whales producing mostly tonal FM calls have been reported (Ljungblad et al., 1984a, 1985a; Würsig et al., 1985). Such differences may result in different proportions of calls being recorded depending on the behavior of the subject whales. In addition, variation in sea state and ice conditions will affect the attenuation of each call type somewhat differently, depending on their physical qualities, and therefore, the proportion of calls recorded in the sample.

Calf Sightings and Estimated Recruitment

Sixty-six bowhead calves have been seen in the Beaufort and Chukchi Seas since 1979 (Table 45). Bowhead calf distribution in 1986 was similar to, but not comprehensive of, the distribution of calves seen in the Alaskan Beaufort Sea from 1982-85 (Clarke et al., 1987), and there appeared to be no clear temporal

Table 46. Semimonthly sightings and estimated Gross Annual Recruitment Rate (GARR)* of bowhead calves, 1979-86.

Year	1-15 Aug	16-31 Aug	1-15 Sep	16-30 Sep	1-24 Oct	Total
1979	0	0	0	0	6(0.05)	6(0.03)
1980	0	0	0	0	1(0.08)	1(0.02)
1981	-	0	1(0.02)	1(0.01)	1(0.02)	3(0.01)
1982	5(0.05)	6(0.16)	4(0.07)	7(0.03)	1(0.02)	23(0.05)
1983	2(0.04)	1(0.10)	3(0.12)	3(0.06)	4(0.11)	13(0.08)
1984	0	0	0	2(0.01)	3(0.03)	5(0.01)
1985	0	1(0.09)	0	3(0.09)	3(0.05)	7(0.05)
1986	1(0.08)	1(0.03)	0	1(0.03)	5(0.13)	8(0.05)
TOTAL	8(0.05)	9(0.08)	8(0.03)	17(0.02)	24(0.05)	66(0.04)

*GARR = Number calves/total number bowheads

segregation of calf sightings when abundance indices were compared. Monthly abundance estimates (CPUE) were identical for August, September, and October (0.04), and ranged from 0.01 to 0.36 (Table 44). Highest CPUE by month occurred in block 5 in August and September (0.10), and block 7 in October (0.36). Overall, highest CPUE for 1979-86 was in block 5 (0.09) although this was not significantly higher than any other block. The relatively high calf abundance estimate for block 5 may support Davis', et al. (1983) theory of age class segregation (larger adults offshore, juveniles and cow-calf pairs nearshore) in the Canadian Beaufort, but may also be because overall bowhead abundance is high in the block (Table 31).

Gross annual recruitment rates (GARR), calculated from data collected on line transect, connect and search surveys for August through October, ranged from 0.01 to 0.08, with an overall estimate of 0.04 (Table 46). The 1986 estimate of 0.05 was the same as that calculated for 1982 and 1985, and higher than that calculated for all other fall seasons, except 1983 (0.08). The GARR calculated for 1983 (7.56) was significantly higher than the GARR estimate of all other years combined ($X^2 = 9.11$, df = 2, $p < 0.01$). Chapman (1984a) indicates that line transect and search surveys may not effectively sample all age-sex components of the population, and resulting recruitment rates should be corrected by a factor derived from

Table 47. Monthly summary of gray whale sightings (number of sightings/number of whales), fall 1980-86.

	August	September	October	November	TOTAL
1980	0[a]	0	44/125	60/163	104/288
1981	33/55	0	0	0	33/55
1982	0	5/18	6/8	0	11/26
1983	2/14	1/2	6/10	0	9/26
1984	16/33	7/70	6/12	0	29/115
1985	0	0	0	0	0
1986	0	42/130	15/26	0	57/156
TOTAL	51/102	55/220	77/181	60/163	243/666

[a] 3/3, Canadian Beaufort Sea; Rugh and Fraker, 1981.

behavioral surveys (Chapman, 1984b). However, Clarke et al. (1987) suggest that line transect methodologies incorporating brief periods of circling over sightings, to allow for photography or brief behavioral observations, may result in uncorrected GARR estimates similar to those obtained during behavioral surveys. Therefore, the line transect/search survey combination used to collect these data may provide effective area coverage as well as a methodology that allows for the derivation of GARR and density, provided the data are carefully coded as to when the survey goes off transect.

Gray Whale

Patterns of Distribution, Relative Abundance and Density

Since 1980, 243 of 666 gray whales have been sighted from August through November (Table 47). There were 337 gray whales seen on surveys flown in October and November 1980 and August 1981, in the northern Bering Sea, with 6 gray whales seen in the northeastern coastal Chukchi Sea. In addition, 3 gray whales were seen in the Canadian Beaufort Sea by researchers on the primary aircraft (N780) in August 1980 (Rugh and Fraker, 1981). Since 1982, all fall surveys have been conducted in the Beaufort and northeastern Chukchi Seas between August and October, with a total of 323 grays seen. The following is a review of these latter data only.

Gray whale fall distribution in the northeastern Chukchi Sea has been primarily along the coast between Icy Cape and Pt. Barrow (Figure 38). In September 1982-84, grays were seen along the coastal Chukchi Sea between Wainwright and Barrow (Moore et al., 1986a) while in 1985-86 grays were also seen offshore to 166°20'W in 1985 (K. Frost, personal communication[9]) and to 163°W in 1986 (Figure 37). In October, grays were generally found along the northeastern Chukchi coast between Pt. Hope and Pt. Barrow (Figure 38).

The highest gray whale relative abundance in the Chukchi Sea was calculated for block 13 (WPUE = 2.46), with lesser WPUE calculated for blocks 14 (WPUE = 2.00) and 22 (WPUE = 1.59) (Table 48). Monthly WPUE values decreased from August to September except in blocks 13 and 14. In block 13, WPUE was 3.04 in August, 5.30 in September, and 0.51 in October. In block 14, WPUE was 1.37 in August, 3.70 in September, and 0.73 in October. The drop in relative abundance between September and October corresponds with reports that gray whales begin their fall migration from summer feeding grounds in mid-October (Berzin, 1984; Braham, 1984). In block 22, WPUE was 0 in August and September and 1.94 in October. This increase also may be attributed to migratory timing of southbound gray whales passing through the coastal Chukchi Sea in October.

Habitat Relationships and Behavior

Of the 323 gray whales seen in fall since 1982, 96 percent (n = 310) were in open water or light ($\leq$20%) ice cover and 4 percent (n = 13) were in 71 to 90% cover. Grays were found in water from 5-m to 51-m deep ($\bar{x}$ = 26.78, 13.03 s.d., n = 106). Whales seen along the shoreline appeared to be in water shallow enough to allow them to rest on the bottom.

The majority (81%, n = 263) of gray whales seen in fall were feeding (Table 49) and were often sighted in the presence of mud plumes. Most feeding gray whales (79%, n = 207) were seen in the nearshore areas of blocks 12, 13, and 17, and the remainder were seen offshore in blocks 14 (n = 55) and 18 (n = 1). Gray whales have also been seen swimming (15%, n = 50), diving (1%, n = 3), and resting (1%, n = 4). Three gray whales were observed involved in mating activity and one was seen breaching.

Calf Sightings and Estimated Recruitment

Two gray whale calves have been seen in the fall over five seasons. One was seen on 17 August 1983 among a group of 12 adult whales that were feeding northeast of Point Barrow (71°16.6'N, 156°11.5'W). And one was seen on

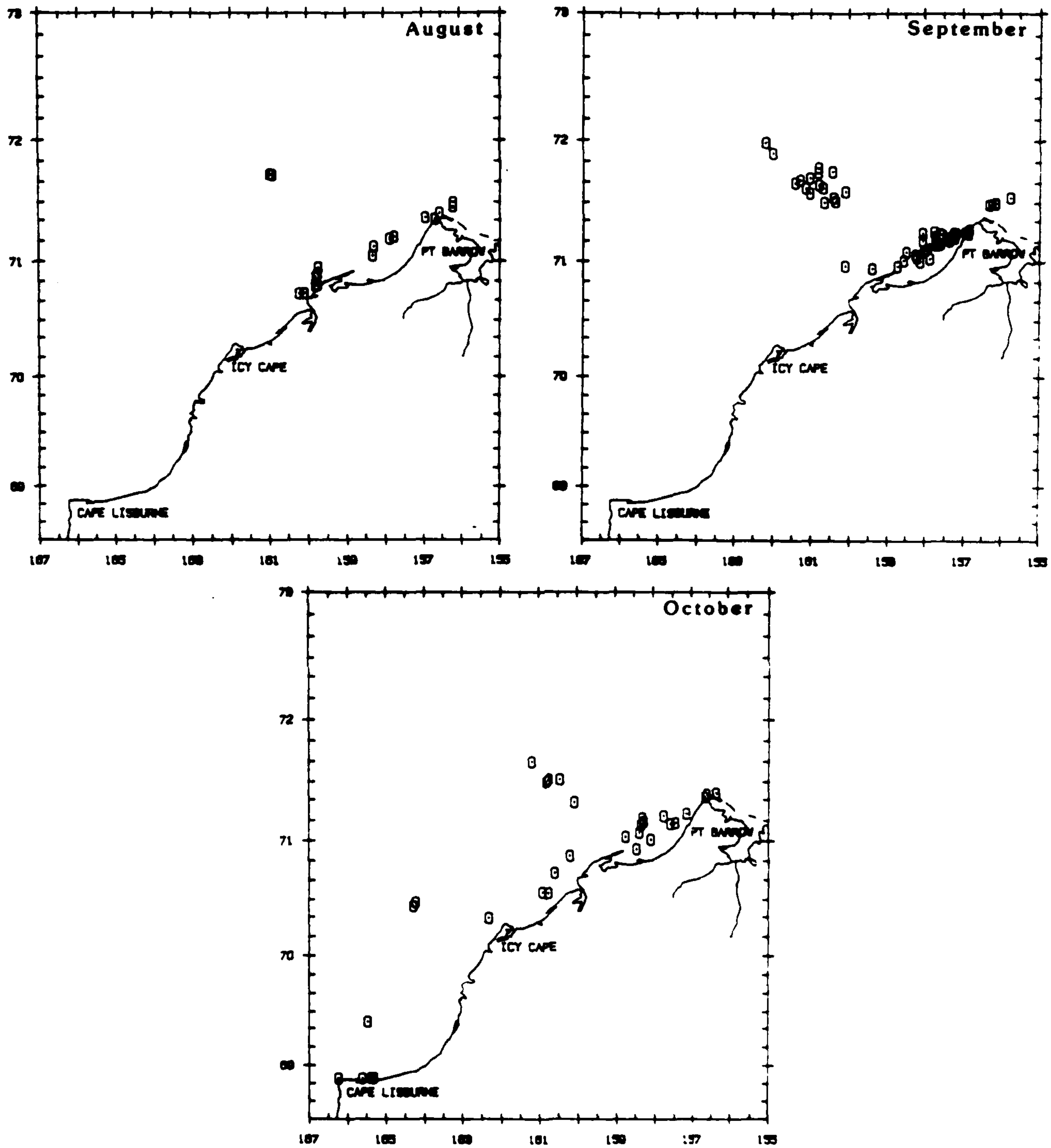


Figure 38. Distribution of 106 sightings of 323 gray whales, August-October 1982-86: 18 sightings of 47 whales, August; 55 sightings of 220 whales, September; 33 sightings of 56 whales, October.

Table 48. Relative abundance of gray whales (WPUE = no. whales/hours of survey effort) by block, fall 1982-86.

Month Block	Aug No. (WPUE)	Sept No. (WPUE)	Oct No. (WPUE)	Total No. (WPUE)
12	17 (2.62)	26 (0.93)	3 (0.05)	46 (0.49)
13	17 (3.04)	**144 (5.30)**	21 (0.51)	**182 (2.46)**
14	3 (1.37)	48 (3.70)	12 (0.73)	63 (2.00)
15	0	0	0	0
16	-	0	-	0
17	**10 (9.52)**	2 (0.24)	5 (0.25)	17 (0.58)
18	0	0	3 (0.25)	3 (0.19)
19	-	-	0	0
20	0	0	5 (0.78)	5 (0.38)
21	0	-	0	0
22	0	0	**7 (1.94)**	7 (1.59)
Total	47 (2.21)	220 (2.42)	56 (0.33)	323 (1.15)

(-) = no effort
Bold indicates peak WPUE.

7 September 1986 also among a group of 12 adults feeding northeast of Point Barrow (71°28.0'N, 156°18.0'W). Resultant GARR estimates were 3.8% in 1983 and 0.6% in 1986. These sightings were farther north than any calves seen during summer surveys from 1980-85 (Ljungblad et al., 1986b).

It appears that gray whale cow-calf pairs may commonly travel as far north as the coastal northeastern Chukchi, or extreme northwestern Beaufort Sea(s). Segregation of cow-calf groups in Alaskan waters was indicated for data gathered in July 1981-83 by a significant difference ($p < 0.005$) in estimated GARR by sea. In the northern Bering Sea, GARR averaged 0.2% over the 3 years, while GARR for the coastal Chukchi Sea averaged 9% (Moore et al., 1986b). Harvest data also indicate that groups remain at least partially segregated on their northern range (Blokhin, 1982; Votrogov and Bogoslovskaya, 1980), and Maher (1960) reported seeing 3 calves near Cape Lisburne and that gray whales taken near Barrow from 1954-59 were either calves ($n = 6$), lactating females, ($n = 2$), or juveniles ($n = 2$). Coastal segregation of cow-calf groups on the northern range may be expected as

Table 49. Summary of gray whale behavior, fall 1982-86.

	August	September	October	Total
Swim				
1982	0	0	1	1 (4)
1983	0	2	3	5 (19)
1984	18	4	2	24 (21)
1986	-	18	2	20 (13)
Total	18	24	8	50 (15)
Dive				
1982	0	0	1	1 (4)
1983	1	0	0	1 (4)
1986	-	1	0	1 (1)
Total	1	1	1	3 (1)
Rest				
1986	-	2	2	4 (2)
Total	-	2	2	4 (1)
Feed				
1982	0	18	6	24 (92)
1983	13	0	7	20 (77)
1984	15	66	10	91 (79)
1986	-	105	21	126 (81)
Total	28	189	44	263 (81)
Display				
1986	-	1	0	1 (1)
Total	-	1	0	1 (0.5)
Mate				
1986	-	3	0	3 (1)
Total	-	3	0	3 (1)
None-Recorded				
1986	-	0	1	1 (1)
Total	-	0	1	1 (0.5)
Annual Total				
1982	0	18	8	26
1983	14	2	10	26
1984	33	70	12	115
1986	-	130	25	156
Total	47	220	56	323

an extension of parturition and migratory segregation (Swartz, 1986; Herzing and Mate, 1984). The extreme northern extension of their range is somewhat surprising however, since cow-calf pairs appear to leave the breeding lagoons after all other adults have left, and migrate north as the second phase of a two-part migration that trails the first phase by 3 to 5 weeks (Poole, 1984; Hessing 1983). The relative protection provided by the shallow coastal zone may be why cow-calf groups remain there. Poole (1984) suggests the extreme coastal migratory corridor used by cow-calves provides protection from predators and a chance for females to feed opportunistically as they migrate north. Upon reaching arctic waters, cows with calves may simply continue this coastal strategy as a way to avoid predators and maintain closer physical contact with the calf through the avoidance of protracted feeding dives.

Other Marine Mammals

Belukha

Since 1979, 4669 belukhas have been seen in the Alaskan Beaufort and northeastern Chukchi Seas in fall. Because widespread survey coverage of both nearshore and offshore areas has been carried out each fall only since 1982, analysis of belukha data presented here includes only those data. Of the 4575 belukhas seen since 1982 (Figure 39), the majority (90%, n = 4123) were in the Beaufort, with 10 percent (n = 452) in the northeastern Chukchi Sea.

Areas of greatest belukha abundance (WPUE) in August were blocks 12, 9, 8, and 10, where WPUE was 11.69, 4.50, 3.66 and 3.34 respectively (Table 50). Blocks 11, 12, and 10 had highest abundance in September (24.77, 20.84, and 12.38 respectively). In October, block 9 had the highest WPUE, with 34 belukhas seen in 0.62 hours, for a value of 54.84. Other offshore blocks (blocks 10, 11, and 12) also had relatively high WPUE. Overall, block 11 had the highest WPUE for 1982-86 at 16.36.

Belukhas have been seen approximately 0.5 to 260 km from shore. Mean depth at sightings decreased from August ($\bar{x}$ = 1132 m, s.d. = 1185, n = 194) to October ($\bar{x}$ = 322 m, s.d. = 493, n = 219), and averaged 837 m (range 5-3504 m, s.d. = 1017, n = 771) for the season. Belukhas were seen in ice cover ranging from 0 to 99 percent (Table 51). The majority were seen in either relatively heavy (61-99%) ice (64%, n = 2950) or extremely light (0-10%) ice (20%, n = 298). Few (16%, n = 697) were seen in areas of light to moderate ice cover (11-60%).

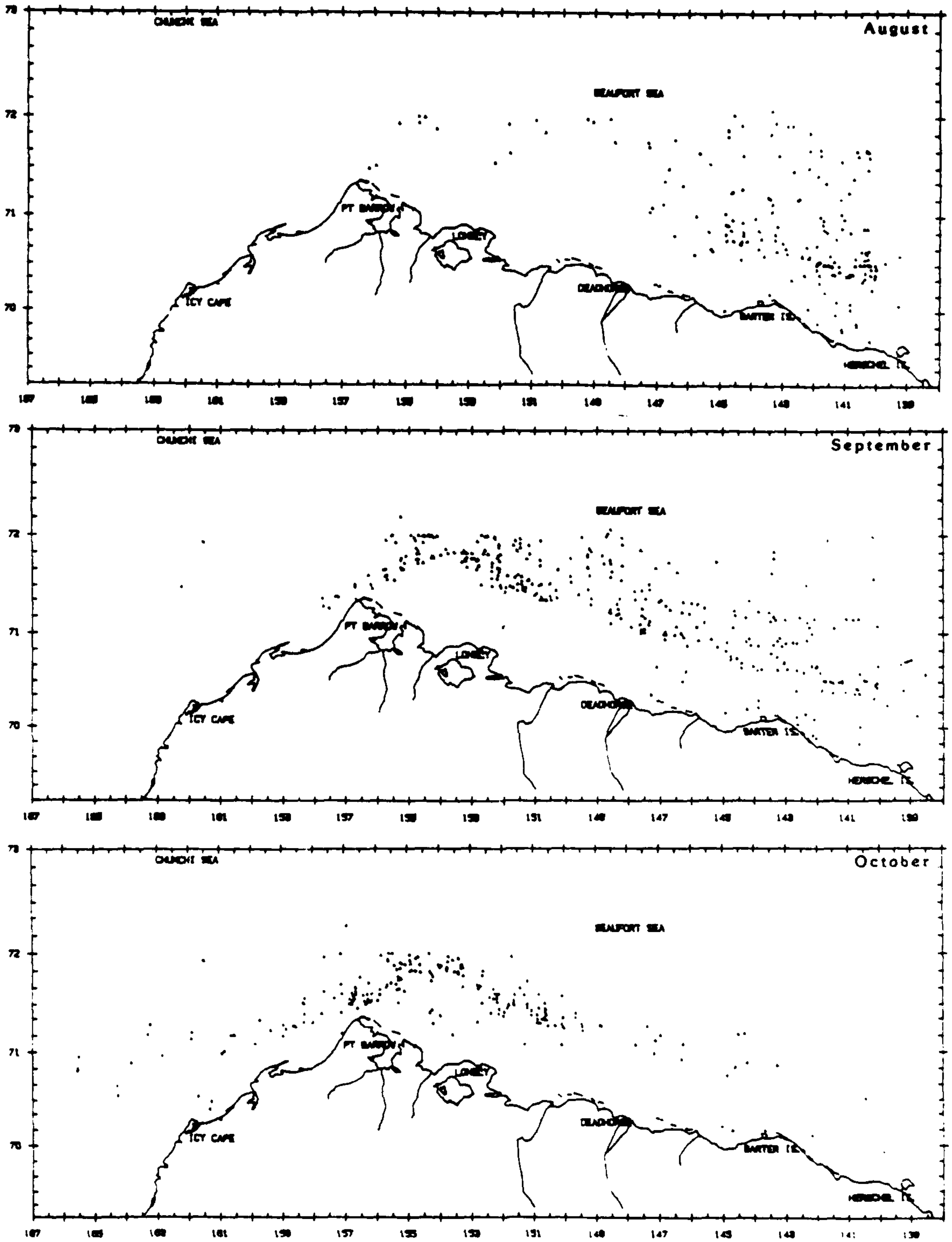


Figure 39. Distribution of 771 sightings of 4575 belukhas, August-October 1982-86: 194 sightings of 588 whales, August; 358 sightings of 2503 whales, September; 219 sightings of 1484 whales, October.

Table 50. Relative abundance of belukhas (WPUE = no. whales/hours of survey effort) by block, fall 1982-86.

Month Block	August No.	(WPUE)	September No.	(WPUE)	October No.	(WPUE)	Total No.	(WPUE)
1	0	-	10	(0.12)	0	-	10	(0.06)
2	20	(1.97)	252	(10.00)	51	(3.74)	323	(6.59)
3	0	-	3	(0.06)	298	(6.16)	301	(2.64)
4	2	(0.03)	11	(0.24)	3	(0.15)	16	(0.13)
5	152	(1.94)	81	(1.43)	1	(0.06)	234	(1.54)
6	80	(1.83)	182	(4.63)	12	(0.99)	274	(2.88)
7	80	(1.63)	192	(6.68)	5	(1.14)	277	(3.37)
8	70	(3.66)	5	(0.35)	0	-	75	(2.20)
9	63	(4.50)	73	(5.84)	**34**	**(54.84)**	170	(6.27)
10	20	(3.34)	199	(12.38)	15	(8.47)	234	(9.83)
11	12	(2.46)	**600**	**(24.77)**	249	(10.58)	**861**	**(16.36)**
12	**76**	**(11.69)**	583	(20.84)	550	(9.22)	1209	(12.84)
13	0	-	197	(7.25)	138	(3.36)	335	(4.53)
14	0	-	11	(0.85)	65	(3.96)	76	(2.41)
15	0	-	0	-	11	(2.10)	11	(0.80)
16	-	-	0	-	-	-	0	-
17	0	-	0	-	10	(0.50)	10	(0.34)
18	0	-	0	-	22	(1.80)	20	(1.41)
Canada	7	(1.15)	73	(10.78)	5	(0.57)	85	(3.93)
Unblocked	6	(4.92)	31	(8.36)	15	(1.60)	52	(3.64)
Total	588	(1.58)	2503	(5.09)	1484	(4.08)	4575	(3.73)

Bold indicates peak WPUE.

The majority of belukhas (78%, n = 3548) seen were swimming. Other behaviors included diving (1%, n = 23), resting (3%, n = 141), milling (8%, n = 466), and cow-calf interaction (10%, n = 466). Headings were clustered around a significantly westerly direction each month during fall. The mean heading in August was 284° T (n = 162, z = 10.09, p < 0.001), 269°T in September (n = 261, z = 35.15, p < 0.001), and 266° T in October (n = 140, z = 29.93, p < 0.001).

Table 51. Number (No.) and percent (%) of belukhas found in each ice cover class, fall 1982-86.

Ice Cover (%)	Aug No.	Aug (%)	Sept No.	Sept (%)	Oct No.	Oct (%)	Total No.	Total (%)
0-10	187	(32)	458	(18)	283	(19)	928	(20)
11-20	11	(2)	34	(1)	29	(2)	74	(2)
21-30	21	(4)	76	(3)	9	(1)	106	(2)
31-40	19	(3)	68	(3)	32	(2)	119	(3)
41-50	19	(3)	168	(7)	27	(2)	214	(5)
51-60	21	(4)	157	(6)	6	(1)	184	(4)
61-70	52	(9)	320	(13)	121	(8)	493	(11)
71-80	66	(11)	427	(17)	436	(29)	929	(20)
81-90	124	(21)	682	(27)	458	(31)	1264	(28)
91-99	68	(11)	113	(5)	83	(5)	264	(5)
Total	588		2503		1484		4575	

Belukhas seen in the Alaskan Beaufort and northeastern Chukchi Seas during August-October are part of a population estimated at 11,500 (Davis and Evans, 1982) that summers in the Canadian Beaufort and overwinters in the Bering and southern Chukchi Seas. Most of the migration appears to pass through offshore areas, but sightings have been made in nearshore shallow areas as well and, in fall 1986, belukha calls were occasionally heard at the acoustic monitoring station on Barter Island. This indicates that at least a portion of the population that is seen nearshore in the Canadian Beaufort during July and early August (Davis and Evans, 1982) remains nearshore during their migration through Alaskan waters, although the main body of the population passes offshore in deeper waters.

Walrus

Since 1982, 3499 walruses have been seen in the western Beaufort and northeastern Chukchi Seas in fall (Figure 40). More walruses were seen during October (61%, n = 2124) than during any other month (Table 52), and more (75%, n = 2608) were seen in 1983 than in any other year. Our distribution and numbers, however, were probably related to survey effort and/or prevailing ice conditions.

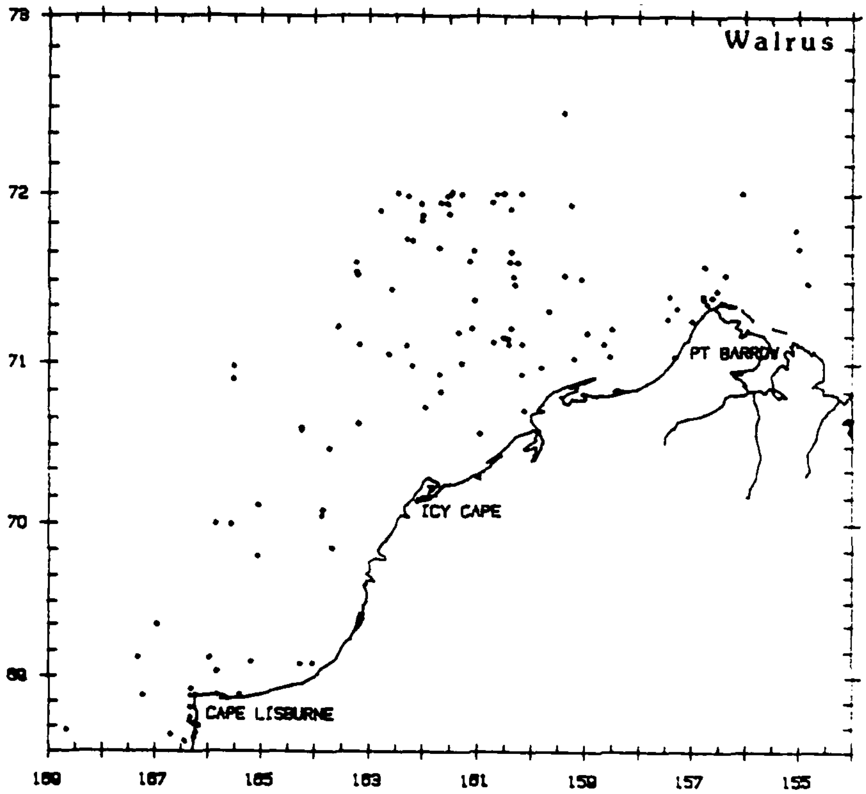


Figure 40. Distribution of 216 sightings of 3499 walrus, August-October 1982-86.

Nearly twice as much survey coverage was completed in the Chukchi Sea in October, when ice conditions tended to be heavier, than in August and September (Table 31). And more Chukchi Sea survey coverage was completed in 1983 when ice conditions remained heavy throughout the entire fall season than in any other year, except 1986 when ice conditions were extremely light. Walruses, which tend to stay along the ice edge in the Chukchi Sea, have been sighted more often in years and months in which ice cover was the highest.

Walruses have been seen both in water and on the ice. In August, they were usually seen either in areas of light ice (0-20% cover; 51%, n = 128) or hauled out in areas of heavy ice (71-100% cover; 34%, n = 81) (Table 52). In September, the majority were seen in areas of relatively heavy ice (61-90% cover; 74%, n = 844). Most (67%, n = 1433) walrus seen in October were in areas of moderate (41-50% coverage) ice. Walruses have been seen both singly and in groups of 2 to 400. Most group sizes were estimated and, because the main objectives of surveys were to collect endangered whale data, some group sizes were the result of "running counts" leading to lumping of data. Therefore, an analysis of walrus group size data was not undertaken.

Table 52. Monthly summary of walrus sightings (number of sightings/number of animals), and number (No.) and percent (%) of walruses found in each ice cover class, 1982-86.

Month	August	September	October	Total
Year				
1982	0	1/1	17/457	18/458
1983	6/62	42/906	36/1640	104/2608
1984	28/179	13/129	3/3	44/311
1985	0	0	0	0
1986	0	42/98	8/24	50/122
Total	34/241	98/1134	84/2124	216/3499

Ice Cover (%)	No. (%)	No. (%)	No. (%)	No. (%)
0-10	94 (39)	111 (10)	240 (11)	445 (13)
11-20	29 (12)	63 (6)	0	92 (3)
21-30	1 (1)	0	1 (0)	2 (0)
31-40	0	100 (9)	0	100 (3)
41-50	36 (15)	15 (1)	1433 (67)	1484 (42)
51-60	0	1 (0)	2 (0)	3 (0)
61-70	0	491 (43)	26 (1)	517 (15)
71-80	35 (14)	142 (12)	4 (1)	181 (5)
81-90	40 (17)	211 (19)	411 (19)	662 (19)
91-100	6 (2)	0	7 (1)	13 (0)
Total	241	1134	2124	3499

Specific behavioral information was not often recorded for walrus seen on this project, but most were either swimming or hauled out on the ice. While it was difficult to positively document behaviors beyond the aforementioned broad categories, many that were swimming may have been feeding. Walruses feed at depths of 10-50 m (Fay, 1981); in the northeastern Chukchi they have been seen in water 5- to 336-m deep ($\bar{x}$ = 41.01, s.d. = 31.96, n = 213). In the northern Bering Sea, walruses feed on benthic bivalves (Oliver et al., 1983a), and probably feed on similar species in the northeastern Chukchi Sea as well (J. Oliver, personal communication[6]).

Walruses were not often seen in association with other pinnipeds, but have been found in close proximity to gray whales, particularly in offshore areas. In 1986, gray whales and walruses were seen closely associated with one another in block 14, often in instances where the whales were feeding. Gray whales and walruses probably do not feed in the same geographic locales, however, because their preferred prey species are very different. While both are benthic invertebrate feeders, walruses prefer bivalve clams including *Mya truncata*, *Serripes groenlandicus* and *Macoma* spp. (Oliver et al., 1983a), and gray whales appear to feed mostly on amphipods, including *Pontoporeia femorata* and *Ampelisca macrocephala* (Oliver et al., 1983b). The differences in preferred prey and the availability of the prey account for differences in distribution in the northern Bering Sea (Nelson and Johnson, 1987), and may also serve to segregate the two species on their feeding grounds in the northeastern Chukchi Sea.

Bearded Seal

Three hundred thirty-one bearded seals were seen distributed across the Alaskan Beaufort and northeastern Chukchi Seas during fall since 1982 (Figure 41, Table 53). The greatest percentage of animals were seen in August (48%, n = 159), with fewer seals seen as the season progressed, resulting in the smallest percentage seen in October (15%, n = 51). Possibly, bearded seals were easier to positively identify while they were swimming in the water due to their size and coloration. Relatively few bearded seals have been seen since 1984 (n = 61), perhaps as a result of increasing the aircraft survey altitude from 305 m (1000 ft) to 457 m (1500 ft) thereby decreasing the number of pinnipeds that could be positively identified.

Burns (1981) indicated that bearded seals avoid regions of continuous, shore-fast ice, as well as areas of unbroken, heavy, drifting ice, and instead utilize areas of shallow open water. Most bearded seals (44%, n = 145) seen since 1982 were in

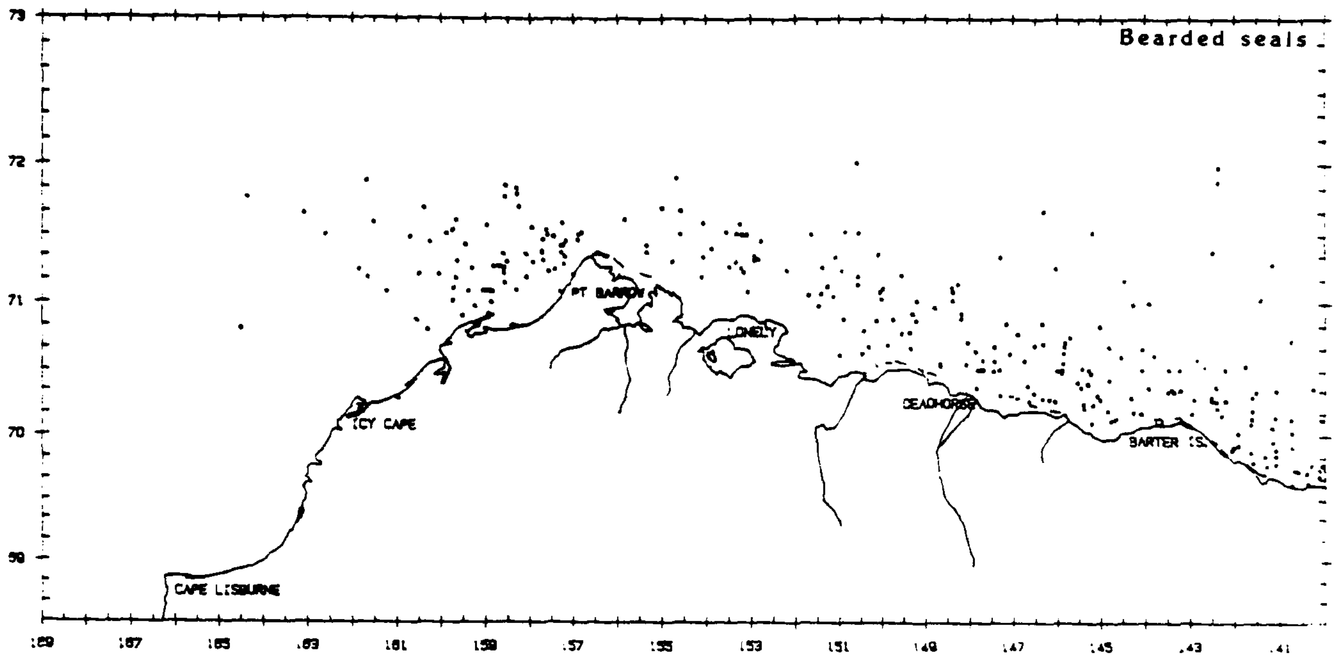


Figure 41. Distribution of 273 sightings of 331 bearded seals, August-October 1982-86.

extremely light (0-10%) ice cover with the remaining 56 percent distributed fairly evenly about other ice classes (Table 53). They have been seen from 0.5 to 240 km offshore, although most sightings were within 100 km (Figure 41). Bearded seals were seen in water depths ranging from 5-3255 m ($\bar{x}$ = 162.3, 529.9 s.d., n = 271). These seals may be utilizing the Chukchi and Beaufort Seas as feeding areas, primarily the epibenthos. Bearded seals may dive to depths of 200 m to prey on crabs, clams, and shrimps in the Chukchi Sea, and crabs, shrimps, and arctic cod in the Beaufort Sea (Burns, 1981).

Ringed Seal

Three hundred seventy-three ringed seals have been seen in fall since 1982 (Figure 42, Table 54). Like bearded seals, their distribution was widespread throughout the Beaufort and Chukchi Seas. Most ringed seals were seen in the water during August and September, and resting on the ice near breathing holes in October. They have been found in each ice cover class, although half (50%, n = 186) were seen in light to moderate ice (0-20% ice). As with other pinnipeds seen in these surveys, the behavior of ringed seals was hard to document. More than likely, ringed seals seen swimming were also feeding on such prey items as

Table 53. Monthly summary of bearded seal sightings (number of sightings/number of animals), and number (No.) and percent (%) of bearded seals found in each ice cover class, 1982-86.

Month	August	September	October	Total
Year				
1982	6/6	8/8	2/9	16/23
1983	24/27	27/33	8/11	59/71
1984	80/92	45/57	24/27	149/176
1985	5/5	9/12	2/2	16/19
1986	22/29	9/11	2/2	33/42
Total	137/159	98/121	38/51	273/331

Ice Cover (%)	No. (%)	No. (%)	No. (%)	No. (%)
0-10	65 (41)	60 (50)	20 (39)	145 (44)
11-20	12 (8)	10 (8)	3 (6)	25 (8)
21-30	14 (9)	5 (4)	1 (2)	20 (6)
31-40	15 (9)	3 (3)	1 (2)	19 (6)
41-50	5 (3)	6 (5)	6 (12)	17 (5)
51-60	8 (5)	5 (4)	2 (4)	15 (4)
61-70	4 (2)	10 (8)	1 (2)	15 (4)
71-80	8 (5)	10 (8)	2 (4)	20 (6)
81-90	14 (9)	10 (8)	4 (8)	28 (9)
91-100	14 (9)	2 (2)	11 (21)	27 (8)
Total	159	121	51	331

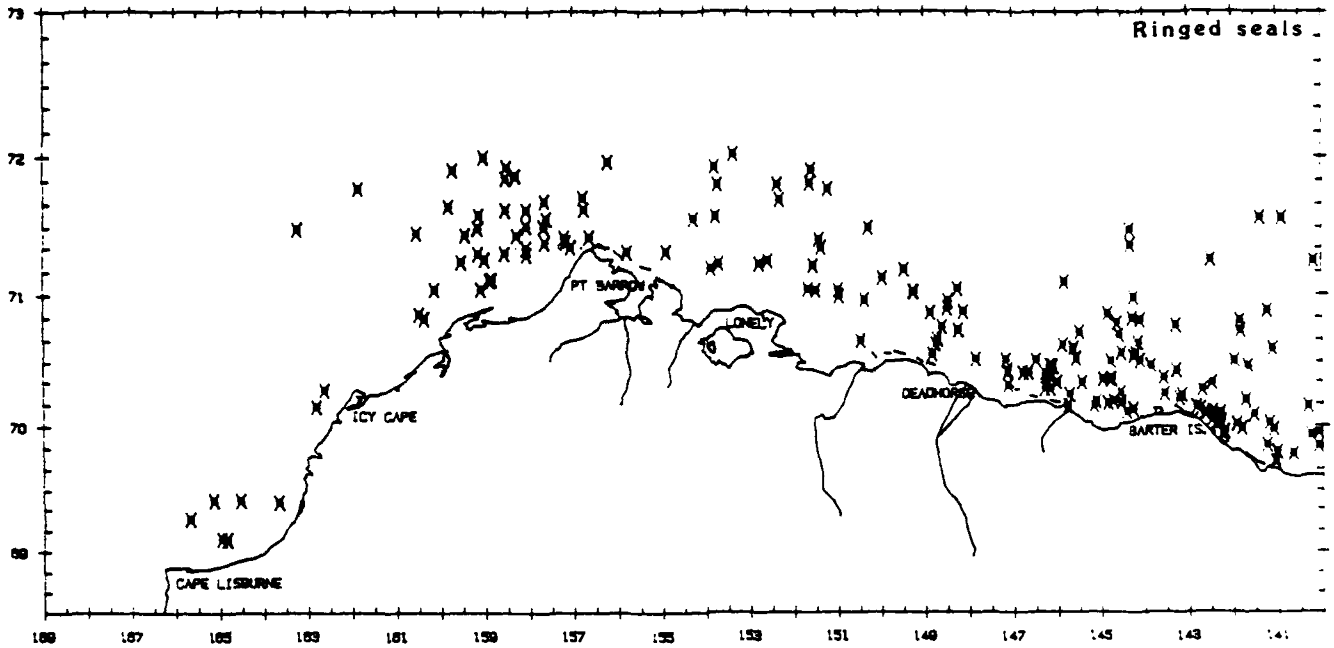


Figure 42. Distribution of 189 sightings of 373 ringed seals, August-October 1982-86.

arctic cod (Boreogadus saida) and large zooplankton (Parathemisto libellula and Thysanoessa spp.) (Lowry et al., 1980).

Polar Bear

Polar bears seen in the Beaufort and Chukchi Seas are part of a population estimated at 1,300 to 2,500 animals, that ranges from Pt. Barrow east to Cape Bathurst, Northwest Territories, Canada (Amstrup et al., 1986). Since 1982, 92 sightings of 148 polar bears, including 21 cubs and 5 juveniles, have been made in the Alaskan Beaufort and northeastern Chukchi Seas in fall (Figure 43, Table 55). More bears (n = 84) were seen in 1983 (heavy-ice year) than in all other years combined, and more bears have been seen in October (n = 65), when the ice is heaviest, than in any other month. Overall, most (74%, n = 109) were seen in areas of heavy (71-100%) ice cover.

Polar bears were usually seen as singles, in adult pairs, or as family groups with a sow and one (7 occurrences) or two (7 occurrences) cubs. Rarely were more than 2 adults seen together, although on one occasion 19 bears, including 13 adults and 6 cubs, were seen at a feeding site north of Smith Bay (26 September 1983).

Table 54. Monthly summary of ringed seal sightings (number of sightings/number of animals), and number (No.) and percent (%) of ringed seals found in each ice cover class, 1982-86.

Month	August	September	October	Total
Year				
1982	6/7	1/1	25/69	32/77
1983	1/3	0	2/2	3/5
1984	72/96	42/69	2/2	116/167
1985	0	1/1	0	1/1
1986	2/2	35/121	0	37/123
Total	81/108	79/192	29/73	189/373

Ice Cover (%)	No. (%)	No. (%)	No. (%)	No. (%)
0-10	22 (21)	128 (67)	1 (1)	151 (41)
11-20	8 (7)	27 (14)	0	35 (9)
21-30	7 (6)	7 (3)	0	14 (4)
31-40	13 (12)	3 (2)	0	16 (4)
41-50	8 (7)	2 (1)	0	10 (3)
51-60	4 (4)	0	0	4 (1)
61-70	7 (6)	0	13 (18)	20 (5)
71-80	5 (5)	4 (2)	11 (15)	20 (5)
81-90	18 (17)	1 (1)	17 (23)	36 (10)
91-100	16 (15)	20 (10)	31 (43)	67 (18)
Total	108	192	73	373

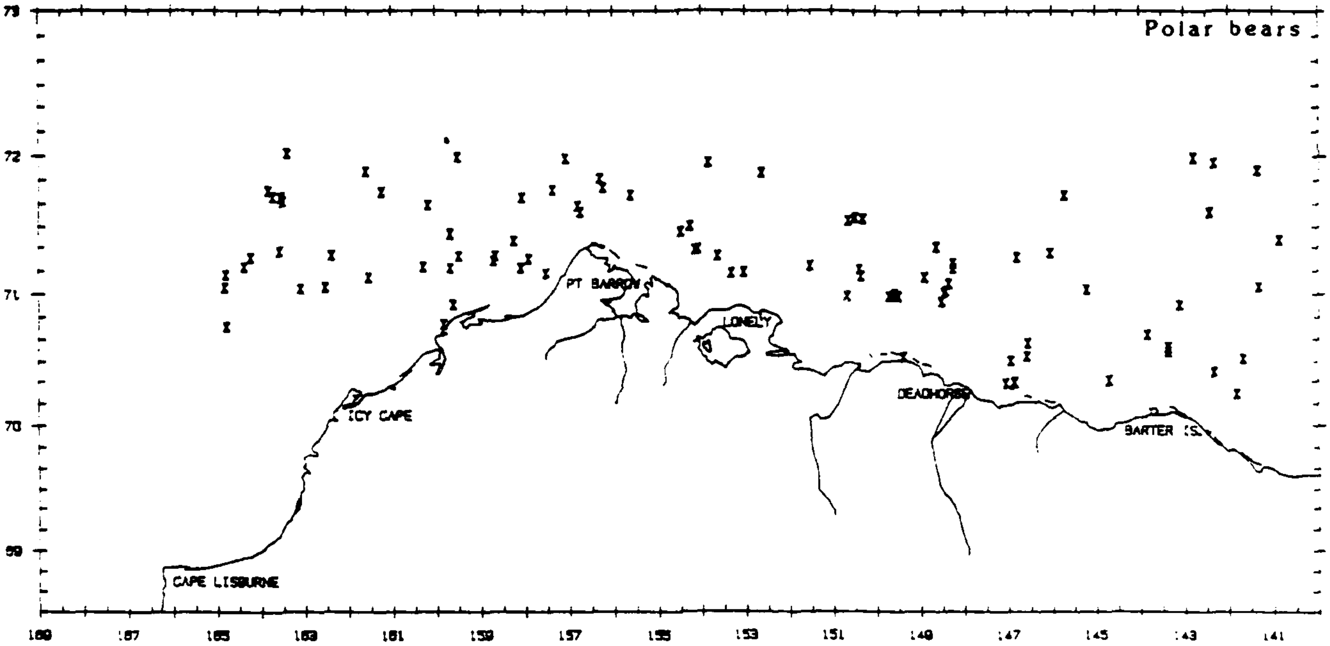


Figure 43. Distribution of 92 sightings of 148 polar bears, August-October 1982-86.

Acoustic Monitoring Effort and Conditions

The acoustic monitoring feasibility study conducted north of Barter Island in 1986 provided an effective means for passively detecting bowheads passing near (≤20 km) the station. Recordings were made on 42 days from 25 August through 11 October resulting in over 590 hours of tape. The field conditions during the acoustic study were very conducive to the monitoring effort. Storms were brief and usually followed by periods of good weather that permitted modified sonobuoys to be replaced or refitted with new battery packs on a semiregular basis. The light-ice conditions throughout September and early October also contributed to the success of the study. Heavy-ice conditions would have either prevented the mooring of sonobuoys from the small boat, or pulled sonobuoys off their mooring and dragged them away. The back up systems of recording from survey-aircraft-deployed sonobuoys helped breach gaps in effort caused by heavy ice, limiting deployment opportunities.

Acoustic Environment of the Shallow Eastern Alaskan Beaufort Sea

Although comprehensive measurements of underwater ambient, industrial, and biological sounds were beyond the scope of the acoustic monitoring study, an

Table 55. Monthly summary of polar bear sightings (number of sightings/number of animals), and number (No.) and percent (%) of polar bears found in each ice cover class, 1982-86.

Month	August	September	October	Total
Year				
1982	7/7	3/3	8/11	18/21
1983	3/4	22/47	20/33	45/84
1984	8/12	3/4	3/6	14/22
1985	0	1/1	3/5	4/6
1986	2/2	2/3	7/10	11/15
Total	20/25	31/58	41/65	92/148
Ice Cover (%)	No. (%)	No. (%)	No. (%)	No. (%)
0-10	4 (16)	4 (7)	1 (2)	9 (6)
11-20	0	0	0	0
21-30	3 (12)	1 (2)	0	4 (3)
31-40	0	2 (3)	1 (2)	3 (2)
41-50	2 (8)	1 (2)	3 (4)	6 (4)
51-60	1 (4)	1 (2)	1 (2)	3 (2)
61-70	3 (12)	5 (8)	6 (9)	14 (9)
71-80	2 (8)	25 (43)	5 (8)	32 (22)
81-90	5 (20)	16 (28)	23 (35)	44 (30)
91-100	5 (20)	3 (5)	25 (38)	33 (22)
Total	25	58	65	148

effort is made below to interrelate the levels recorded from these sources. A comprehensive review of ambient sea noise is presented in Wenz (1962) and Urick (1983). Ambient and industrial noise levels in cold water regions were reviewed in Richardson et al. (1983), and in the shallow Beaufort Sea in Buck (1981), Greene (1985), and Moore et al. (1984). Biological sounds in northern seas were also reviewed in Richardson et al. (1983).

Ambient Noise

In general, the ambient noise of shallow arctic waters may be expected to show more extremes than in other seas, or in deeper water. Wenz (1962) identified the primary sources of ambient noise as wind, shipping, and biological sources. In the Beaufort Sea, ice and offshore oil activities also contribute to the ambient environment. Over the course of a season, ambient levels may fall below those expected for calm seas when ice cover is nearly solid and shipping is all but eliminated. Conversely, ice-grinding noises and vessel noises may result in higher than expected ambient levels. For example, average source spectrum level of pressure ridge noise was reported as 133 dB re 1 μPa, with tonal components to 136 dB (Buck and Greene, 1979). In addition, Diachok (1980) reported relatively high ambient levels of 86 dB at 100 Hz at a compact water-ice boundary. As a result, bowhead whales as well as other arctic marine mammals are likely subjected to a wide range of ambient noise levels.

The shallow eastern Alaskan Beaufort Sea can be an extremely quiet ambient environment when ice is out and seas are calm. Measured ambient level during these conditions averaged 65 dB between 15 Hz and 200 Hz, and 60 dB over the 200-Hz to 500-Hz frequency band. These levels correspond roughly to a Knudsen sea state 2, and are similar to levels reported for this region from data collected in 1979-82 from aircraft deployed sonobuoys (Moore et al., 1984). During storms or heavy-ice conditions, ambient level was about 14 dB higher than quiet ambient levels, averaging approximately 74 dB in the 100-Hz to 500-Hz frequency band. Although components attributable to ice scrapping were evident on spectrums, peak levels were relatively low.

The higher ambient levels measured during heavy-ice and storm-sea conditions in 1986 were well below levels that bowheads are likely subjected to, but may have contributed to somewhat lower call counts at the acoustic station by masking bowhead sounds. Although it appears the detection of calling whales was quite good overall, some calls were undoubtedly "washed out" by the higher ambient background noise.

Industrial Noise

The noise of outboard motors was the most common man-made noise source recorded during the acoustic monitoring study. Characterizing noise from outboards is difficult because both the frequency and level received at the hydrophone will vary not only with the range of the boat, but also with its speed and aspect. In general, measured nearfield outboard noise was 80 dB, or about 20 dB above quiet ambient levels in the 15- to 500-Hz frequency band. Outboard noise spectrums had many peaks associated with propeller cavitation that had energy to 98 dB. Although the nearfield noise levels from outboards is relatively high, they are a transient noise source and, therefore, do not generally contribute to any long term increase in noise levels.

Engine and airgun noise were often heard at the acoustic station. Except for tonal components to 78 dB at about 60 Hz, the level of engine noise for the day recorded was lower (40 dB) than the average ambient noise for the area (60 dB). Greene (1985) notes that ambient levels in the shallow Beaufort Sea often range below levels typical of sea state zero. The day on which the best sample of engine noise was recorded appeared to be such a day. A capture of airgun noise showed elevated levels centered around 100 Hz with a peak of 97 dB at about 75 Hz. Such an airgun "signature" is consistent with reported results of comprehensive analyses of airgun sounds (Greene, 1985; Ljungblad et al., 1985b: Appendix A).

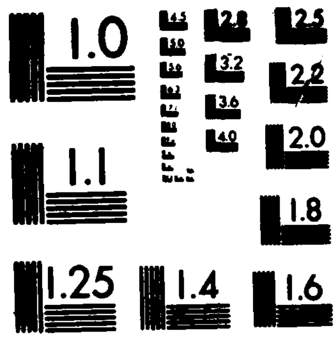
Marine Mammal Sounds

Marine mammal sounds recorded at the acoustic monitoring station included bowhead and belukha calls, as well as numerous bearded seal trills. Although the focus of the study was bowhead calls, notation of calls of other marine mammals was kept in the daily acoustic log and on call tally sheets.

Bearded seal trills were recorded over a longer time period than either bowheads or belukhas. The distinctive trill vocalization was common on tapes recorded from 3 September through the end of the study. Stirling et al. (1983) reported that bearded seal calls in the Canadian high arctic were most numerous near the ice edge, and that under ideal conditions these vocalizations might be heard 45 km from the source. It has been suggested that bearded seal trills are produced by adult males during courtship (Ray et al., 1969), although Burns (1981) suggests that females also vocalize. In general, vocalization rates increase through early spring to a peak in April and May in the Bering Sea, and in June in the Canadian high arctic. The bearded seal trills recorded at the acoustic station may simply represent a tapering off of call rate during the fall.

AD-A183 934 DISTRIBUTION ABUNDANCE BEHAVIOR AND BIOACOUSTICS OF ENDANGERED WHALES IN T..(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA D K LJUNGBLAD ET AL. JUL 87 NOSC/TR-1177 3/5

UNCLASSIFIED F/G 8/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Belukha calls were also recorded at the acoustic station, although not as frequently as bearded seals or bowhead whales. Belukhas produce a wide variety of relatively high-frequency calls (Fish and Mowbray, 1962), and migrate west across the Beaufort Sea somewhat farther offshore than bowheads in the fall (see Figure 39). Because high frequencies are generally attenuated over shorter distances than lower frequencies, their offshore distribution probably contributed to the low incidence of belukha call reception at the acoustic station.

Bowhead calls recorded at the acoustic station were similar to those described in earlier reports (Ljungblad et al., 1982b; Clark and Johnson, 1984). A variety of tonal, frequency-modulated calls were recorded as well as the more complex strident calls generally associated with socializing whales. Although call type was not ascribed to all tallied calls, the incidence of the complex calls appeared to be highest on 28 September, the day of peak call rate for the season. We assume from the elevated call rate that more whales were near the acoustic station on 28 September than any other day and it is not unreasonable to assume that some of these whales were socializing. The high incidence of tonal calls on other tapes is also in keeping with the overall trend of resting and swimming (i.e. migrating) whales to produce these types of calls (Ljungblad et al. 1986b; Würsig et al., 1985). Specifically, the up (FM_1) and down (FM_2) calls may serve to keep migrating whales in contact with one another. In a study of the call repertoire of the southern right whale (Eubalena australis), Clark (1982) found that the average frequency of the "up" call coincided with the low noise band of ambient noise and suggested the calls were used as contact calls. Right whale "up" calls are very similar to bowhead "up" (FM_1) calls and may serve a similar function. A future study of frequency content of bowhead FM_1 calls in relation to local ambient noise conditions may allow a better analytical comparison of this supposition for the two species.

Assessment of Bowhead Whale Occurrence and Movements in the Eastern Alaskan Beaufort Sea via Passive Acoustics

The incidence of bowhead calling recorded at the acoustic monitoring station seemed to provide a good representation of bowhead occurrence and movement through the eastern Alaskan Beaufort Sea. Daily call rates corresponded well with the sighting rates derived via aerial surveys. The calls recorded on 9 September and 11 September bracketed the NMFS-recognized 10 September migratory start date. Further, peak call rates were recorded at the acoustic station for the same

period, roughly 25 September to 7 October, that sighting rates were high. Passive acoustics, therefore, seem to provide a means of addressing bowhead movements during the fall migration. Similar passive acoustic techniques have been employed during the bowhead spring migration since 1982 (Clark et al., 1986; Cummings and Holliday, 1983). Although spring acoustic efforts often included an array of hydrophones that permit localization and tracking of calling whales, the overall results of the two studies were similar in their endorsement of acoustic techniques to detect migrating bowhead whales.

CONCLUSIONS AND RECOMMENDATIONS

Aerial surveys for endangered whales have been conducted over Alaskan Beaufort Sea OCS planning areas since 1979, with transect surveys over the northeastern Chukchi Sea commencing in 1982. Although there are obvious limitations inherent to interpreting data on whales derived via aerial surveys, flying remains the best means of sampling these large offshore areas over a short time period. A data base compiled over several seasons provides an overview to endangered whale habitat use and aids in decision making relative to the leasing and development of the Alaskan OCS. In 1986, an acoustic study was added to the survey effort in the Alaskan Beaufort Sea, which provided additional information on endangered whale temporal occurrence. The following is a conclusion summary and recommendations for future field efforts in the Alaskan Beaufort and eastern Chukchi Seas.

Endangered Whales in the Alaskan Beaufort Sea (1979-86)

Conclusions

1. Bowhead whales inhabit eastern Alaskan and western Canadian Beaufort Sea waters throughout August and mid-September, and are distributed across the Alaskan Beaufort Sea and into the northeastern Chukchi Sea from mid-September through late October.

2. With the exception of a few whales ($\leq$50 whales) that seem to feed in coastal waters east of Barter Island, bowheads seen in the Alaskan Beaufort Sea in August are generally farther offshore and in deeper water than those seen in September and October.

3. The annual variation in bowhead distribution in the Alaskan Beaufort Sea during the 1979-86 fall migration did not appear to be as great as that described for bowheads summering in the Canadian Beaufort Sea between 1980 and 1984 (Richardson et al., 1985a).

4. There may be considerable movements of whales back and forth between the Canadian and Alaskan Beaufort Seas prior to the onset of the migration.

5. The fall bowhead migration began between 2 and 7 September in all years except 1979 (20 August) and 1985 (22 September), and lasted an average of 43 days. Determining the onset and termination of the migration from aerial surveys alone is somewhat difficult and subject to the level and direction of survey efforts that often may be weather-limited.

6. Bowhead relative abundance indices (SPUE and WPUE) tended to be lower and to occur earlier in the migratory period during years of heavy-ice cover compared to years of light-ice cover.

7. Bowhead daily sighting rates were relatively low and few whales were seen feeding in the Alaskan Beaufort Sea west of Barter Island in 1986, a year of light-ice cover. This pattern was more similar to past heavy-ice (1980, 1983-1985 intermediate), rather than light-ice (1979, 1981-82, 1984) years. The reason(s) for the low rates and lack of feeding whales may be, (a) bowheads continued to feed in the Canadian Beaufort Sea until late September, then simply swam through the Alaskan Beaufort Sea as ice was forming in October or (b) bowheads migrated west along the ice edge where local upwelling may have influenced prey production and provided feeding opportunities. The 1986 season was unique with respect to the distance the ice edge was offshore during September and early October, and may somehow account for the sparsity of nearshore feeding.

8. Ice cover was negatively associated with bowhead relative abundance as calculated by WPUE ($r = -0.746$, $p \leq 0.05$) and 5-day SPUE peak (-0.625, $p \leq 0.10$). The negative correlation of ice cover with sighting distance ($r = -0.164$, $p \leq 0.001$) likely influences these results.

9. Although there was some annual variability in observed bowhead whale distribution during the fall 1979-86 migrations, it appears that except for 1983, the migration route may be roughly demarcated by the 20- to 40-meter isobath, and that the effects of OCS oil and gas development activities on the axis of the bowhead whale migration (as defined by median depth) are slight.

10. Although the 1983 migration route could be said to be displaced offshore compared to other years, it is not likely that this was the result of industrial activities because such activities were curtailed that year. Additionally, the migratory axis since 1983 (i.e., 1984-86) was similar to years 1979-82.

11. Based on 1983 results, it is possible that the 1980 migration proceeded farther offshore than aerial surveys were flown that year and went largely undetected.

12. As described in Ljungblad et al. (1986a,c) whales passing through the Alaskan Beaufort Sea stop to feed opportunistically. Feeding whales were seen in shallower water and in lighter-ice cover than whales not feeding; and so, the annual availability of prey will influence somewhat the water

depth and ice cover in which whales are found. The lack of quantitative information regarding the effect of ice cover and/or oceanographic processes along the shelf break (or ice edge) on the distribution of bowheads or their prey somewhat confounds the interpretation of data on bowhead distribution.

13. Bowheads seem to produce more tonal-type (FM) calls when swimming and diving, and more growl-like (AM) calls when involved in social behaviors.

14. Bowhead GARR has averaged 5% over the years. There appears to be little or no geographic nor temporal segregation of calves during the fall migration.

15. Calls recorded at the acoustic monitoring station on Barter Island indicated that the largest aggregation of bowheads migrated through the eastern Alaskan Beaufort Sea in late September through early October, 1986. Call rate was highest on 28 September (88.09 calls/hour), which corresponded exactly to the date of peak WPUE (6.01) and SPUE (4.96) for the season.

Recommendations

1. In addition to conducting line transect surveys in the established survey blocks, transect surveys at the ice edge should be conducted periodically to assess bowhead occurrence there. Bowheads seem to be strongly associated with the ice edge as they overwinter in the Bering Sea (Ljungblad et al., 1986b: Appendix E; Brueggeman et al., 1984; Brueggeman, 1982). A similar association may be true during fall migrations when a defined ice edge exists far offshore over water deep enough to permit ice-induced upwelling.

2. Information from the acoustic station at Barter Island would be enhanced by upgrading the system to provide directional information for calling whales.

Endangered Whales in the Northeastern Chukchi Sea (1982-86)

Conclusions

1. Gray whales and bowhead whales are commonly seen nearshore between Point Barrow and Icy Cape; grays occur from July through mid-October, bowheads from mid-September through October.

2. Bowheads seem to disperse across the Chukchi Sea, with some whales swimming southwest across Herald Shoal.

3. Survey block 13 supported relatively high abundance indices of gray whales and bowhead whales, although there was not much overlap in their temporal occurrence.

4. Gray whales were seen feeding farther offshore in the northeastern Chukchi Sea in 1986 than in any other year, resulting in high offshore relative abundance indices.

5. Gray whales involved in mating behavior were observed just west of Barrow on 7 September 1986. This may be the most northerly record for gray whale mating behavior.

Recommendations

1. An extension of transect survey effort to the offshore ice edge would provide additional information on bowhead and gray whale distribution, relative abundance and behaviors for this area.

2. More time allocated to the deployment of sonobuoys near foraging gray whales would enhance interpretation of bioacoustic behavior for this species.

3. Further comparisons of bowhead and gray whale temporal use and habitat preferences should be made in the Chukchi Sea Planning Area.

4. Increase survey effort in the southern Chukchi Sea (Blocks 20, 22) to document habitat use by gray whales, and the presence or absence of cow-calf pairs.

5. An acoustic station could be maintained at Barrow to monitor bowhead arrival and presence of gray whales. A full scale station, similar to that at Barter Island, would be most desirable. If this were not practical, sonobuoys dropped from the survey aircraft could provide 6 to 8 hours of acoustic sampling if a receiving station were maintained.

PERSONAL COMMUNICATION LIST

1. Pam Norton, ESL Environmental Sciences Limited, 2035 Mills Rd., RR#2, Sidney, British Columbia, Canada V8L 3S1

2. John Richardson, LGL Limited, 22 Fisher Street, P.O. Box 457, King City, Ontario, Canada, LOG 1KO

3. Steve Johnson, LGL Limited, 9768 Second St., Sidney, British Columbia, Canada, V8L 3Y8

4. Ken Vaudrey, ERA Flight Services, Anchorage, AK

5. Byron Morris, National Marine Fisheries Service, Anchorage, AK, 99510

6. John Oliver, Moss Landing Marine Lab, P.O. Box 223, Moss Landing, California, 95039

7. John Ford, ESL Environmental Sciences Limited, 34-1035 Richard St., Vancouver, B.C. V6B 3E4

8. Douglas Chapman, C8S-HR20, University of Washington, Seattle, Washington, 98195

9. Kathy Frost, Alaska Dept. of Fish and Game, 1300 College Ave., Fairbanks, AK, 99701

REFERENCES

Amstrup, S.C., I. Stirling, and J.W. Lentfer. 1986. Past and present status of polar bears in Alaska. Wildl. Soc. Bull. 14: 241-254.

Baker, C.S. and L.M. Herman. 1984. Aggressive behavior between humpback whales (Megaptera novaeangliae) wintering in Hawaiian waters. Can J. Zool. 62(10): 1922-1937.

Baker, C.S., L.M. Herman, B.G. Bays, and G.B. Bauer. 1983. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska: 1982 season. Rep. to Mar. Mamm. Lab. Seattle, WA. 31 pp.

Batschelet, E. 1972. Recent statistical methods for orientation data. pp 41-61, In: Animal Orientation and Navigation, S.R. Galler, K. Schmidt-Koenig, G.J. Jacobs and R.E. Bellevue (eds.). NASA, Washington, D.C. 360 pp.

Bauer, G.B. and L.M. Herman. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawaii. Final Report for the National Marine Fisheries Service, Honolulu, HI, prepared by the Univ. of Hawaii. 151 pp.

Berzin, A.A. 1984. Soviet studies on the distribution and numbers of the gray whale in the Bering and Chukchi Seas from 1968 to 1982. pp. 409-419, In: The Gray Whale, M.L. Jones, S.L. Swartz, and J.S. Leatherwood (eds.). Academic Press, Inc., San Francisco, CA. 600 pp.

Blokhin, S.A. 1982. Investigations on gray whales taken off Chukotka in 1980. Rep. int. Whal. Commn. 32: 375-80.

Bockstoce, J.R. 1986. Whales, Ice and Men. The History of Whaling in the Western Arctic. University of Washington Press, Seattle, WA. 400 pp.

Bockstoce, J.R. and D.B. Botkin. 1983. The historical status and reduction of the western arctic bowhead whale (Balaena mysticetus) population by the pelagic whaling industry, 1948-1914. Rep. int. Whal. Commn. (Spec. Iss. 5): 107-141.

Bogoslovskaya, L.S., L.M. Votrogov and T.N. Semenova. 1981. Feeding habits of gray whales off Chukotka. Rep. int. Whal. Commn. 31: 507-510.

Braham, H.W. 1984. Distribution and migration of gray whales in Alaska. pp. 249-266, In: The Gray Whale, M.L. Jones, S.L. Swartz, and J.S. Leatherwood (eds.). Academic Press, Inc., San Francisco, CA. 600 pp.

Braham, H.W., M.A. Fraker, and B.D. Krogman. 1980. Spring migration of the western Arctic population of bowhead whales. Mar. Fish. Rev. 42(9-10): 36-46.

Braham, H.W., B.D. Krogman and G.M. Carroll. 1984. Bowhead and white whale migration, distribution and abundance in the Bering, Chukchi and Beaufort Seas, 1975-78. NOAA Technical Report NMFS SSRF-778. 39 pp.

Breiwick, J.M., E.D. Mitchell and D.G. Chapman. 1981. Estimated initial population size of the Bering Sea stock of bowhead whale (Balaena mysticetus): an iterative method. U.S. Fish. Bull. 78(4): 843-853.

Brueggeman, J.J. 1982. Early spring distribution of bowhead whales in the Bering Sea. J. Wildl. Manage. 46: 1036-1044.

Brueggeman, J.J., R.A. Grotefendt, and A.W. Erickson. 1984. Endangered whale surveys of the Navarin Basin, Alaska. Envirosphere Company, Bellevue, WA. Unpublished report to OCSEAP, Juneau, AK. 73 pp.

Bryant, P.J., C.M. Lafferty and S.K. Lafferty. 1984. Reoccupation of Laguna Guerro Negro, Baja California Mexico, by gray whales. pp. 375-87, In: The Gray Whale, M.L. Jones, S.L. Swartz and J.S. Leatherwood (eds.). Academic Press, 600 pp.

Buck, B.M. 1981. Compilation of underwater acoustic ambient noise data in shallow Beaufort and Chukchi Seas. Unpubl. report by Polar Research Lab, Inc., Santa Barbara, CA for the Sohio Alaska Petroleum Company, Anchorage. 50 pp.

Buck, B.M. and C.R. Greene. 1979. Source level measurements of an arctic sea ice pressure ridge. J. Acoust. Soc. Am. (Suppl. 1) 66: 525-526.

Burns, J.J. 1981. Bearded Seal, Erignathus barbatus. pp. 145-170, In: Handbook of Marine Mammals, Vol. 2, S.H. Ridgway and R.J. Harrison (eds.). Academic Press, Inc. New York. 359 pp.

Chapman, C.F. 1971. Piloting, Seamanship and Small Boat Handling. Hearst Books, New York. 640 pp.

Chapman, D.G. 1984a. Estimates of net recruitment of Alaska bowhead whales and of risk associated with various levels of kill. Rep. int. Whal. Commn. 34: 469-471.

Chapman, D.G. 1984b. Estimate of gross recruitment of Alaska bowhead whales 1979-83. Paper SC/36/PS18 presented to IWC Scientific Committee, June 1984 (unpublished).

Clark, C.W. 1983. The use of bowhead vocalization to augment visual censusing estimates on the number of whales migrating off Barrow, Alaska in the spring of 1980. Paper SC/35/PS13 to the IWC Scientific Committee, June 1983 (unpublished). 20 pp.

Clark, C.W., W.T. Ellison, and K. Beeman. 1985. Acoustic tracking and distribution of bowhead whales, Balaena mysticetus, off Point Barrow, Alaska in the spring of 1984. Paper SC/37/PS11 to the IWC Scientific Committee. June 1985 (unpublished). 25 pp.

Clark, C.W., W.T. Ellison and K. Beeman. 1986. A preliminary account of the acoustic study conducted during the 1985 spring bowhead whale Balaena mysticetus migration off Point Barrow, Alaska. Rep. int. Whal. Commn. 36: 311-16.

Clark, C.W. and J.H. Johnson. 1984. The sounds of the bowhead whale (Balaena mysticetus), during the spring migrations of 1979 and 1980. Can. J. Zool. 62(7): 1436-1441.

Clarke, J.T., S.E. Moore and D.K. Ljungblad. 1987. Observations of bowhead whale (Balaena mysticetus) calves in the Alaskan Beaufort Sea during the autumn migration, 1982-85. Rep. int. Whal. Commn. 37: 287-293.

Cochran, W.G. 1963. Sampling Techniques. J. Wiley, New York. 413 pp.

Cowles, C.J., D.J. Hansen and J.D. Hubbard. 1981. Types of potential effects of offshore oil and gas development on marine mammals and endangered species of the northern Bering, Chukchi and Beaufort Seas Tech. Paper No. 9, Alaska Outer Cont. Shelf Office, U.S. Bureau of Land Mgt. Anchorage, AK. 23 pp.

Cummings, W.C. and D.V. Holliday. 1983. Source level of bowhead whale sounds determined by acoustical array localization. J. Acoust. Soc. Am. (Suppl. 1) 74: 555.

Darling, J.D., K.M. Gibson and G.K. Silber. 1983. Observations on the abundance and behavior of humpback whales (Megaptera novaeangliae) off West Maui, Hawaii, 1977-79. pp. 201-222, In: Communication and behavior of whales, R. Payne (ed.). AAAS Selected Symposium 76, Westview Press, Boulder, CO. 643 pp.

Davis, R.A. and C.R. Evans. 1982. Offshore distribution and numbers of white whales in the eastern Beaufort Sea and Amundsen Gulf, Summer 1981. Rep. by LGL Limited, Toronto, Ontario, for Sohio Alaska Petroleum Company, Anch., AK, and Dome Petroleum Limited, Calgary, Alberta. 76 pp.

Davis, R.A., W.R. Koski, and G.W. Miller. 1983. Preliminary assessment of the length-frequency distribution and gross annual reproduction rate of the western Arctic bowhead whale as determined with low-level aerial photography, with comments on life history. Report by LGL Ecol. Res. Assoc., Inc., for National Marine Mammal Laboratory, NMFS, NOAA, Seattle, WA. 90 pp.

Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans and W.G. Alliston. 1982. Distribution, numbers and productivity of the Western Arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. by LGL Limited, Toronto, Ontario, to Dome Petroleum Limited, Calgary, Alberta, and to Sohio Alaska Petroleum Company, Anchorage, Alaska. 135 pp.

Diachok, O. 1980. Arctic hydroacoustics. Cold Regions Sci and Technol. 2: 185-201.

Dohl, T.P. and R. Guess. 1979. Evidence for increasing offshore migration of the California gray whale, Eschrichtius robustus in southern California, 1975 through 1978, pp. 13, In: Abstracts, 3rd Bienn. Conf. Biol. Mar. Mamm. 7-11 Oct 1979, Seattle, WA.

Eberhardt, L.L. 1978. Transect methods for population studies. 1978. J. Wildl. Mgt. 42: 1-31.

Estes, J.A. and J.R. Gilbert. 1978. Evaluation of an aerial survey of Pacific walruses (Odobenus rosmarus divergens). J. Fish Res. Board Can. 35: 1130-1140.

Evans, W.E. 1982. A study to determine if gray whales detect oil. pp. 47-61, In: Study of the effect of oil on cetaceans, J.R. Geraci and D.J. St. Aubin (eds.). Final Report for U.S. Bureau of Land Management, by Univ. of Guelph. 274 pp.

Fay, F.H. 1981. Walrus, Odobenus rosmarus. pp. 1-23, In: Handbook of Marine Mammals, Vol. 1, S.H. Ridgway and R.J. Harrison (eds.). Academic Press, Inc. New York. 255 pp.

Fish, M.P. and Mowbray, W.H. 1962. Production of underwater sound by the white whale or beluga, Delphinapterus leucas. J. Mar. Res. 20(2): 149-162.

Ford, J. 1975. Sound production by the beluga whale, Delphinapterus leucas, in captivity. The University of British Columbia ms., 25 April 1975. 36 pp.

Fraker, M.A. and J.R. Bockstoce. 1980. Summer distribution of bowhead whales in the eastern Beaufort Sea. Mar. Fish. Rev. 42(9-10): 57-64.

Fraker, M.A., D.K. Ljungblad, W.J. Richardson, and D.R. Van Schoik. 1985. Bowhead whale behavior in relation to seismic exploration, Alaskan Beaufort Sea, Autumn 1981. Report by LGL Ecol. Res. Assoc., Inc. and the Naval Ocean Systems Center, Code 5141, for MMS, Alaska OCS Region. 40 pp.

Frost, K.J. and L.F. Lowry. 1984. Trophic relationships of vertebrate consumers in the Alaskan Beaufort Sea. pp. 381-401, In: The Alaskan Beaufort Sea: Ecosystems and Environments. Academic Press, Inc. Orlando, FL.

Gales, R.S. 1982. Effects of noise of offshore oil and gas operations on marine mammals: an introductory assessment. Vol. 1. NOSC TR844. 79 pp.

Gard, R. 1974. Aerial census of gray whales in Baja California lagoons, 1970 to 1973, with notes on behavior mortality and conservation. Calif. Fish. Game 60(3): 132-143.

Greene, C.R. 1985. Characteristics of waterborne industrial noise, 1980-84. pp. 197-253 In: Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84, W.J. Richardson (ed.). Chapter by Greeneridge Sciences, Inc., in Unpubl. Rep. from LGL Echol. Res. Assoc., Inc. Bryan TX for U.S. Minerals Management Service, Reston, VA. 306 pp.

Hayne, D.W. 1949. An examination of the strip census method for estimating animal populations. J. Wildl. Mgt. 13: 145-147.

Herzing, D.L. and B.R. Mate. 1984. Gray whale (Eschrichtius robustus) migrations along the Oregon coast, 1978-81. pp. 289-307. In: The Gray Whale, M.L. Jones, S.L. Swartz and J.S. Leatherwood (eds). Academic Press Inc., San Francisco, CA. 600 pp.

Hessing, P. 1983. Gray whale (Eschrichtius robustus) migration into the Bering Sea observed from Cape Sarichef, Unimak Island, Alaska, Spring 1981. pp. 47-73. In: Final Report, Outer Cont. Shelf Environ. Asses. Prog. Contract No. NA 81RGA 0080, Vol. 20. 650 pp.

Houghton, J.P., D.A. Segar, and J.E. Zeh. 1984. Beaufort Sea monitoring program: Proceedings of a Workshop (September 1983) and Sampling Design Recommendations. Prepared for the OCS Assessment Program Juneau, Alaska; Prepared by Dames and Moore, Seattle, Washington. 111 pp.

IWC. 1986. Report of the Sub-Committee on protected species and aboriginal subsistence whaling, Rep. int. Whal. Commn. (Annex H.) 36: 95-111.

LaBelle, J.C., J.L. Wise, R.P. Voelker, R.H. Schulze and G.M. Wohl. 1983. Alaska Marine Ice Atlas. AEIDC, University of Alaska, Anchorage, AK. 302 pp.

Leatherwood, S., J.R. Gilbert, and D.G. Chapman. 1978. An evaluation of some techniques for aerial census of bottlenosed dolphins. J. Wildl. Mgt. 42: 239-250.

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1982. Whales, dolphins, and porpoises of the eastern north Pacific and adjacent Arctic waters. NOAA Technical Report NMFS Circular 444. 245 pp.

Ljungblad, D.K. 1981. Aerial surveys of endangered whales in the Beaufort Sea, Chukchi Sea, and northern Bering Sea. NOSC TD 449, prepared for MMS Alaska OCS Office. 302 pp.

Ljungblad, D.K. and S.E. Moore. 1982. Acoustic source level of the bowhead whale (Balaena mysticetus). Unpubl. MS. NOSC 1-82. 8 pp.

Ljungblad, D.K., S.E. Moore, and J.T. Clarke. 1986a. Assessment of bowhead whale (Balaena mysticetus) feeding patterns in the Alaskan Beaufort and north-eastern Chukchi Seas via aerial surveys, Fall 1979-84. Rep. int. Whal. Commn. 36: 265-272.

Ljungblad, D.K., S.E. Moore, J.T. Clarke and J.C. Bennett. 1986b. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1985: with a seven year review, 1979-85. NOSC TR 1111, prepared for MMS Alaska OCS Region. 409 pp.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, D.R. Van Schoik and J.C. Bennett. 1985a. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi, and Alaskan Beaufort Seas, 1984: with a six year review, 1979-1984. NOSC TR 1046, prepared for MMS Alaska OCS Office. 301 pp.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1983. Aerial surveys of endangered whales in the Beaufort, Chukchi and northern Bering Seas, 1982. NOSC TD 605, prepared for MMS Alaska OCS Office. 382 pp.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1984a. Aerial surveys of endangered whales in the Northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1983: with a five-year review 1979-83. NOSC TR 955, prepared for MMS Alaska OCS Office. 356 pp.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1986c. Seasonal patterns of distribution, abundance, migration and behavior of the western Arctic stock of bowhead whales, Balaena mysticetus in Alaskan Seas. Rep. int. Whal. Commn. (Spec. Iss. 8): 177-205.

Ljungblad, D.K., S.E. Moore, D.R. Van Schoik and C.S. Winchell. 1982a. Aerial surveys of endangered whales in the Beaufort, Chukchi and northern Bering Seas. NOSC TD 486, prepared for MMS Alaska OCS Office. 374 pp.

Ljungblad, D.K., M.F. Platter-Rieger and F.S. Shipp, Jr. 1980. Aerial surveys of bowhead whales, North Slope, AK. NOSC TD 314, prepared for MMS Alaska OCS Office. 188 pp.

Ljungblad, D.K., P.O. Thompson, and S.E. Moore. 1982b. Underwater sounds recorded from migrating bowhead whales, (Balaena mysticetus), in 1979. J. Acoust. Soc. Am. 71(2): 477-482.

Ljungblad, D.K., B. Würsig, R.R. Reeves, J.T. Clarke and C.R. Greene. 1984b. Fall 1983 Beaufort Sea seismic monitoring and bowhead whale behavior studies. Report prepared for Minerals Management Service by SEACO, Inc. 180 pp.

Ljungblad, D.K., B. Würsig, and S.L. Swartz. 1985b. Observations on the behavior of bowhead whales (Balaena mysticetus) in the presence of operating seismic exploration vessels in the Alaskan Beaufort Sea. Final Report prepared for the Minerals Management Service, prepared by SEACO, Inc. 78 pp.

Lowry, L.F. and K.J. Frost. 1984. Foods and feeding of bowhead whales in western and northern Alaska. Sci. Rep. Whales. Res. Inst. 35: 1-16.

Lowry, L.F., K.J. Frost, and J.J. Burns. 1980. Variability in the diet of ringed seals, Phoca hispida, in Alaska. Can. J. Fish. Aquat. Sci. 37: 2254-2261.

Macfarlane, J.F. 1981. Reactions of whales to boat traffic in the area of the confluence of the Saguenay and St. Lawrence Rivers. Quebec. Unpubl. MS. 50 pp.

Magnusson, W.E., G.J. Caughley, and G.C. Grigg. 1978. A double-survey estimate of population size from incomplete counts. J. Wildl. Mgt. 42: 174-176.

Maher, W.J. 1960. Recent records of the California gray whale (Eschrichtius robustus) along the north coast of Alaska. Arctic 13: 257-65.

Mate, B. 1987. Development of satellite linked methods of large cetacean tagging and tracking capability in OCS lease areas - Draft Final Report for Minerals Management Service, Alaska OCS Office. 100 pp.

Milne, A.R., J.H. Ganton and D.J. McMillin. 1967. Ambient noise under sea ice and further measurements of wind and temperature dependence. J. Acoust. Soc. Am. 41(2): 525-528.

Moore, S.E., J.T. Clarke and D.K. Ljungblad. 1986a. A comparison of gray whale (Eschrichtius robustus) and bowhead whale (Balaena mysticetus) distribution, abundance, habitat preference and behavior in the northeastern Chukchi Sea, 1982-84. Rep. int. Whal. Commn. 36: 273-279.

Moore, S.E., D.K. Ljungblad, and D.R. Van Schoik. 1986b. Annual patterns of gray whale (Eschrichtius robustus) distribution, abundance and behavior in the northern Bering and eastern Chukchi Seas, July 1980-1983. Rep. int. Whal. Commn. (Spec. Iss. 8): 231-242.

Moore, S.E., D.K. Ljungblad, and D.R. Schmidt. 1984. Ambient industrial and biological sounds recorded in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas during the seasonal migrations of the bowhead whale (Balaena mysticetus), 1979-1982. Final Report for the U.S. Minerals Management Service, by SEACO, Inc. 104 pp.

Naval Hydrographic Office. 1956. Aerial Ice Reconnaissance and Functional Glossary of Ice Terminology. Hydrographic Office Publication Number 609. 14 pp.

Nelson, C.H. and K.R. Johnson. 1987. Whales and walruses as tillers of the sea floor. Sci. Am.

Nerini, M.K. 1984. A review of gray whale (Eschrichtius robustus) feeding ecology. pp. 423-450, In: The Gray Whale, M.L. Jones, S.L. Swartz and J.S. Leatherwood (eds.). Academic Press Inc., San Francisco, CA. 600 pp.

Nishiwaki, M. and A. Sasao. 1977. Human activities disturbing natural migration routes of whales. Sci. Rep. Whales Res. Inst. 29: 113-120.

Norris, K.S. and R.R. Reeves (eds.). 1978. Report on a workshop on problems related to humpback whales (Megaptera novaeangliae) in Hawaii. Unpubl. Rep. from Sea Life, Inc., Makapuu Pt. HI for U.S. Mar. Mamm. Comm., 90 pp.

Oliver, J.S., P.N. Slattery, E.F. O'Connor, and L.F. Lowry. 1983a. Walrus, Odobenus rosmarus, feeding in the Bering Sea: a benthic perspective. Fish. Bull. 81(3): 501-512.

Oliver, J.S., P.N. Slattery, M.A. Silberstein, and E.F. O'Connor. 1983b. A comparison of gray whale, Eschrichtius robustus, feeding in the Bering Sea and Baja California. Fish. Bull. 81(3): 513-522.

Poole, M.M. 1984. Migration corridors of gray whales (Eschrichtius robustus) along the central California coast, 1980-82. pp. 389-407. In: The Gray Whale, M.L. Jones, S.L. Swartz and J.S. Leatherwood (eds.). Academic Press Inc., San Francisco, CA. 600 pp.

Ray, C., W.A. Watkins, and J. Burns. 1969. The underwater song of Erignathus (Bearded seal). Zoologica 54: 79-83.

Reeves, R.R. 1977. The problem of gray whale (Eschrichtius robustus) harassment: at the breeding lagoons and during migration. U.S. Marine Mammal Comm. Rep. MMC-76/06. NTIS PB 272 506, 60 pp.

Reeves, R.R. 1978. The narwhal: the arctic's unicorn. Alaska 44(9): 10-11, 88-89.

Reeves, R.R. and S. Tracey 1980. Mammalian Species (Monodon monoceros). American Society of Mammologists 127: 1-7.

Reeves, R.R., D.K. Ljungblad, and J.T. Clarke. 1983. Report on studies to monitor the interaction between offshore geophysical exploration activities and bowhead whales in the Alaskan Beaufort Sea, Fall 1982. Final Report prepared for the Minerals Management Service, prepared by SEACO, Inc. 80 pp.

Reilly, S.B., D.W. Rice and A.A. Wolman. 1983. Population assessment of the gray whale, (Eschrichtius robustus), from California shore censuses, 1967-80. Fish. Bull. 81(2): 267-281.

Rice, D.W. 1965. Offshore southward migration of gray whales off southern California. J. Mammal. 46: 504-505.

Richardson, W.J. (Ed.) 1987. Importance of the Eastern Alaskan Beaufort Sea to feeding bowhead whales, 1986. Preliminary report from LGL Limited to Minerals Management Service, Anchorage, AK.

Richardson, W.J., R.A. Davis, C.R. Evans, and P. Norton. 1985a. Distribution of bowheads and industrial activity, 1980-84 pp. 255-306. In: Behavior. disturbance responses and distribution of bowhead whales, (Balaena mysticetus) in the eastern Beaufort Sea, 1980-84, W.J. Richardson (ed.). Final Report for the U.S. Mineral Management Service, by LGL Ecol. Res. Assoc., Inc. 306 pp.

Richardson, W.J., C.R. Greene, J.P. Hickie, and R.A. Davis. 1983. Effects of offshore petroleum operations on cold water marine mammals: a literature review. API Rep. No. 4370 Am. Petrol. Inst. Washington DC. 248 pp.

Richardson, W.J., R.S. Wells, and B. Würsig. 1985b. Disturbance responses of bowheads, 1980-84. pp. 89-196, In: Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84, W.J. Richardson (ed.). Final Report for the U.S. Minerals Management Service, by LGL Ecol. Res. Assoc., Inc. 306 pp.

Rugh, D.J. and M.A. Fraker. 1981. Gray whale sightings in the eastern Beaufort Sea. Arctic 34(2): 186-187.

Schell, D.M., P.J. Ziemann, D.M. Parrish, K.H. Danton and E.J. Brown. 1982. Foodweb and nutrient dynamics in nearshore Alaskan Beaufort Sea waters. pp. 327-499, In: Outer Continental Shelf Environmental Assessment Program, Vol. 25. 500 pp.

Smith, T.G. 1977. The occurrence of a narwhal (Monodon monoceros) in Prince Albert Sount, western Victoria Island, Northwest Territories. Can. Field Nat. 91: 299.

Stirling, I., W. Calvert and H. Cleator. 1983. Underwater vocalizations as a tool for studying the distribution and relative abundance of wintering pinnipeds in the high arctic. Arctic 38(3): 262-274.

Swartz, S. 1986. Gray whale migratory, social and breeding behavior. Rep int. Whal. Commn. (Spec. Iss. 8): 207-230.

Tyak, P. and H. Whitehead. 1983. Male competition in large groups of wintering humpback whales. Behaviour 83 (1-2): 132-154.

Urick, R.J. 1983. Principles of Underwater Sound, 3rd ed. McGraw-Hill Book Co. New York, New York. 423 pp.

Votrogov, L.M. and L.S. Bogoslovskaya, 1980. Gray whales off the Chukotka peninsula. Rep int. Whal. Commn. 30: 435-437.

Watkins, W.A. 1967. The harmonic interval: fact or artifact in special analysis of pulse trains. pp. 15-43, In: Marine Bioacoustics, W.N. Travolga (ed.). Permangion Press, New York. 353 pp.

Webster, B.D. 1982. Empirical probabilities of the ice limit and fifty percent ice concentration boundary in the Chukchi and Beaufort seas. National Weather Service, U.S. National Oceanic and Atmospheric Administration, Anchorage, AK NOAA Technical Memorandum NWS AR-34. 9 pp.

Wenz, G.M. 1962. Acoustic ambient noise in the oceans spectra and sources. J. Acoust. Soc. Am. 34: 1936-1956.

Würsig, B., C.W. Clark, E.M. Dorsey, M.A. Fraker, and R.S. Payne. 1985. Normal behavior of bowheads, 1980-84. pp. 13-88, In: Behavior, disturbance responses and distribution of bowhead whales (Balaena mysticetus) in the eastern Beaufort Sea, 1980-84, W.J. Richardson (ed.). Report by LGL Ecol. Res. Assoc., Inc. for U.S. MMS. 306 pp.

Zar, S.H. 1984. Biostatistical Analysis. Prentice Hall, Inc., Englewood Cliffs, N.J. 620 pp.

APPENDIX A

AERIAL SURVEY FLIGHT CAPTIONS, SURVEY TRACKS, AND SIGHTING SUMMARIES, 1986

CONTENTS

INTRODUCTION

This appendix consists of flight tracks, 1 through 55 (N780) and 1 through 23 (302 EH), depicting aerial surveys flown over the eastern Chukchi and Alaskan Beaufort Seas between mid-August and late October 1986. Each flight is represented by a survey track, with all marine mammal sightings plotted, and a caption describing the flight's objectives, survey conditions and sightings. Each symbol on the flight track/sighting charts represents one sighting of one or more animals. Additionally, summary information on bowhead and gray whale sightings is presented beneath the flight caption in the tabularized format:

T#/C#	Total number of whales/total number of calves seen		
LAT/LONG	Location (latitude N/longitude W) in degrees, minutes, and tenths of minutes		
DIS	Perpendicular distance from the aircraft in meters (altitude x cotangent clinometer angle)		
CUE	Sighting cue:		
	BO = Body	MP = Mud Plumes	
	BW = Blow	DY = Display	
	SP = Splash		
BEH	Behavior:		
	SW = Swim	DY = Display	SH = Spyhop
	DI = Dive	MT = Mate	TS = Tail-Slap
	RE = Rest	FE = Feed	BR = Breach
	MI = Mill	CC = Cow-Calf	RL = Roll
	UB = Underwater Blow	DE = Dead	NA = None
HDG	Heading in magnetic degrees		
ICE	Ice cover in percent		
SS	Sea State (Beaufort scale)		
DEPTH	Depth in meters		

Dashes (-) indicate data were not recorded.

Occasionally, both aircraft (N780, 302 EH) completed flights on the same day. In those instances, flight tracks and summary information for both aircraft are presented on the same page. A monthly summary of all marine mammal sightings is provided as an overview of sighting data for the 1986 field season (Table A-1). Species abbreviations used in flight track keys are listed in Table A-1.

Table A-1. Monthly summary of all marine mammal sightings* by species, 1986.

Species	Abbr**	August	September	October	Total
Bowhead Whale (_Balaena mysticetus_)	BH	21/41	57/79	29/38	107/158
Gray Whale (_Eschrichtius robustus_)	GW	0/0	42/130 (2D)	15/26	57/156 (2D)
Belukha (_Delphinapterus leucas_)	BE	28/81	48/200 (1D)	33/211 (2D)	109/492 (3D)
Unidentified Cetacean	CT	0/0	2/3	2/2	4/5
Walrus (_Odobenus rosmarus_)	WS	0/0	42/98 (3D)	8/24 (1D)	50/122 (4D)
Bearded Seal (_Erignathus barbatus_)	BS	22/29	9/11	2/2	33/42
Ringed Seal (_Phoca hispida_)	RS	2/2	35/121	0/0	37/123
Unidentified Pinniped	PN	14/22	147/308	76/155	237/485
Polar Bear (_Ursus maritimus_)	PR	2/2	2/3	7/10	11/15

*The figures shown for each month represent the number of sightings/the number of individuals sighted during that period.

**Abbreviations are those used in flight track legends.

D = Dead

METHODS

Maps were prepared using a series of computer programs consisting of BASIC subroutines implemented on a Hewlett-Packard (HP 85) microcomputer connected to an HP 7470A printer/plotter. The coastlines for each map, digitized on an HP 9111A graphics tablet, were formatted to examine the principal study areas (i.e., the eastern Chukchi Sea, and the Alaskan Beaufort Sea). As a result, a comparison of flight tracks for a given study area can be made on a visual basis over the period of the field season to evaluate ongoing patterns of the animal distribution and aircraft coverage. Each map shows the flight track as a line drawn through position updates recorded on the aircraft computer system. Each animal sighting is marked with a species symbol on the flight track plot. Additional information on survey conditions and sightings provided by the computer log is summarized in the flight captions.

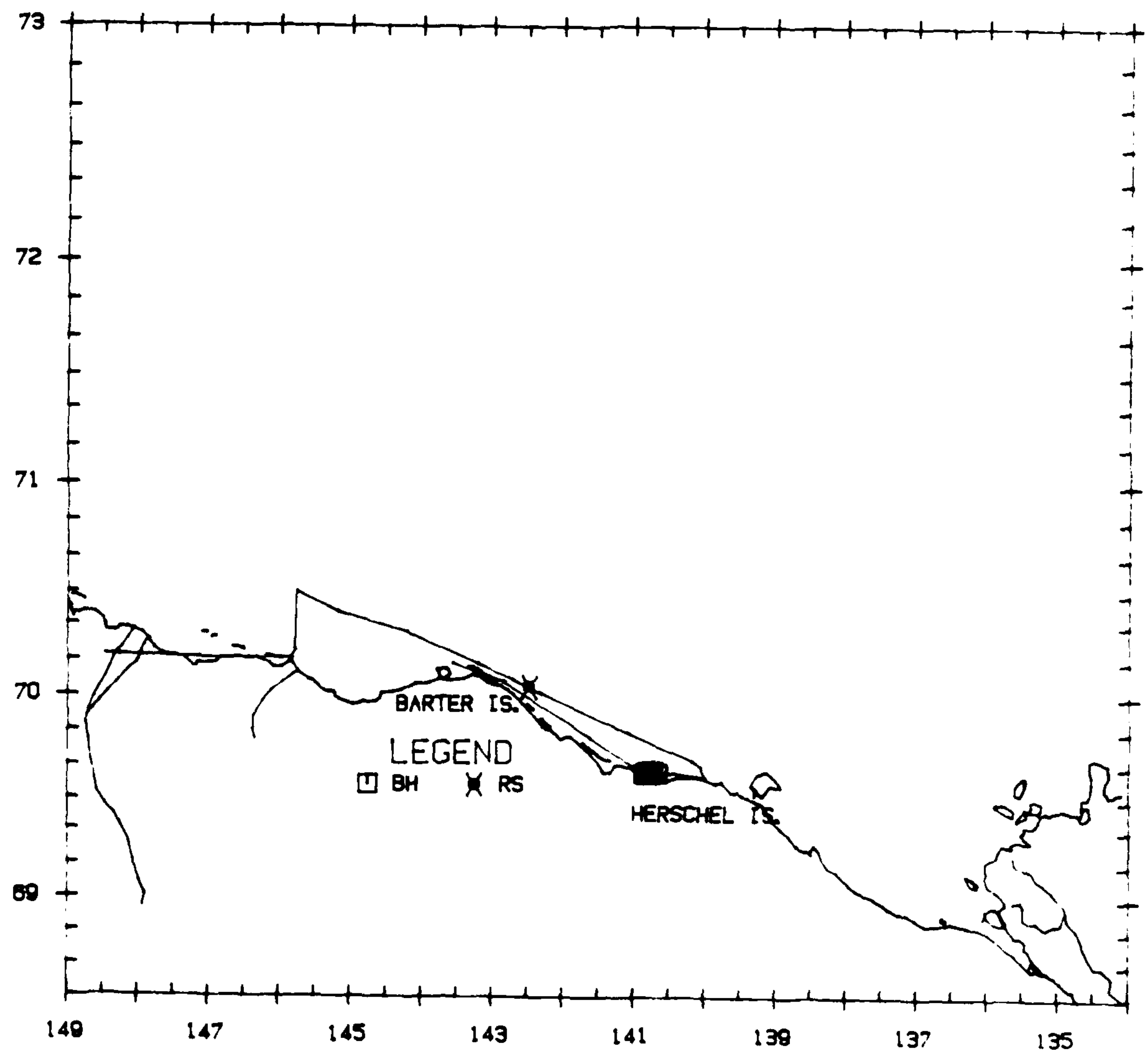
FLIGHT CAPTIONS, SURVEY TRACKS, AND SIGHTINGS SUMMARY

N780
Flight 1: 15 August 1986

Flight was a search survey of blocks 4 and 5, after a transect survey of block 4 was aborted due to heavy low-lying fog. Visibility was ≤1 km in block 4 and ≤5 km in block 5. Ice cover was estimated as 0 to 20 percent and sea state was Beaufort 01 to 02. Twelve bowheads were seen within 0.5 km of shore approximately 52 km west of Herschel Island. These whales were feeding, milling or resting in milky-green water. One ringed seal was also seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°38.1'	140°39.5'	-	BO	RE	-	0	B2	7
1/0	69°38.8'	140°43.7'	-	BO	RE	-	0	B2	7
5/0	69°37.9'	140°45.3'	-	BO	FE	-	0	B2	7
1/1	69°37.6'	140°48.6'	-	BO	SW	-	0	B2	7
3/0	69°38.6'	140°48.9'	-	BW	FE	-	0	B2	7
1/0	69°37.9'	140°51.4'	-	BO	UB	-	0	B2	7



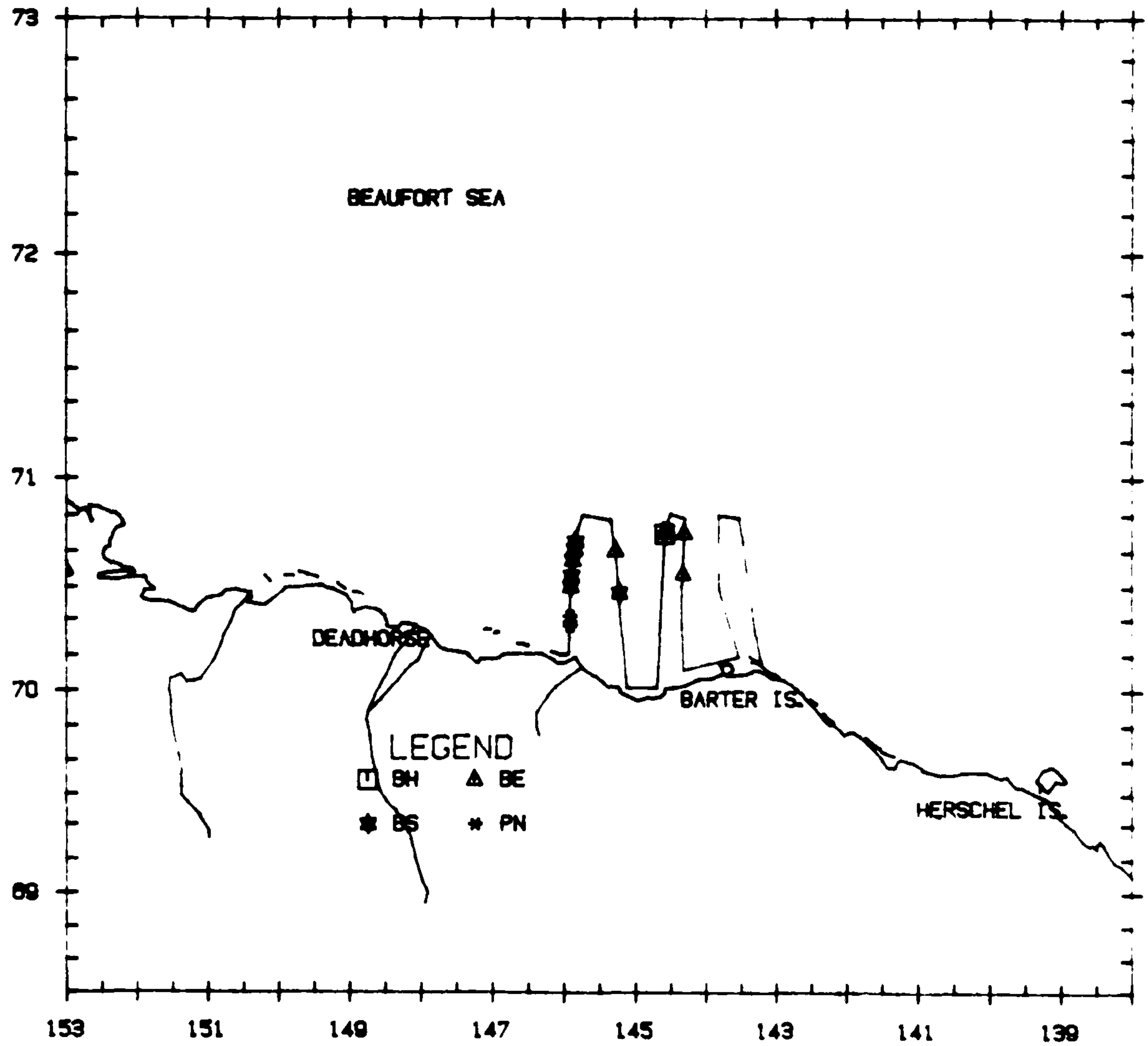
73
72
71
70
69
BARTER IS.
LEGEND
BH
RS
HERSCHEL IS.
149
147
145
143
141
139
137
135

N780
Flight 2: 16 August 1986

Flight was a transect survey of block 4 and the southern one-half of block 6. Weather was clear with unlimited visibility. There were patches of 10-percent ice cover in block 4 and patches of 50-percent ice cover in block 6, although open-water was predominant in both blocks. Sea state was a Beaufort 01. One bowhead was seen in block 6. The whale dove slowly and was not resighted within a quarter hour of circling over the area. Belukhas, bearded seals, and unidentified pinnipeds were also seen.

Bowhead Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°45.1'	144°35.3'	412	BO	RE	-	10	B2	82



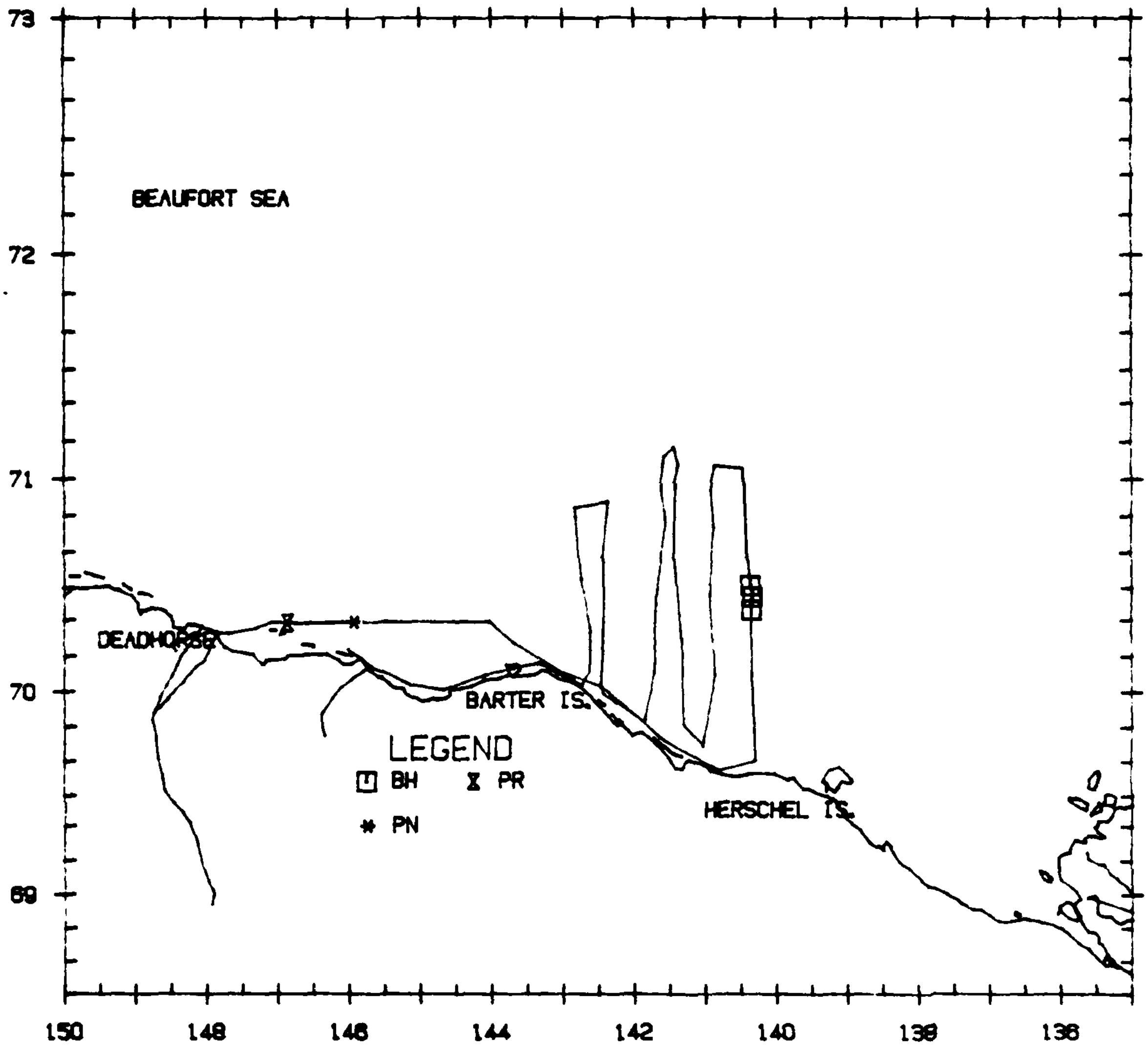
73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
BS
PN
153
151
149
147
145
143
141
139

N780
Flight 3: 17 August 1986

Flight was a transect survey of blocks 5 and 7, with a search survey across block 4. Weather was low overcast with rain showers. Visibility varied from 5 km to unacceptable. All blocks were nearly ice-free, with patches of 5- to 40-percent ice in a 1-km band just north of shore in blocks 4 and 5 and the beginning of a 20- to 60-percent icefield near the northern boundary of block 7. Sea state ranged from Beaufort 02 to 06. Three bowheads were seen on the easternmost transect leg in block 5. A polar bear and unidentified pinnipeds were also seen.

Bowhead Whales

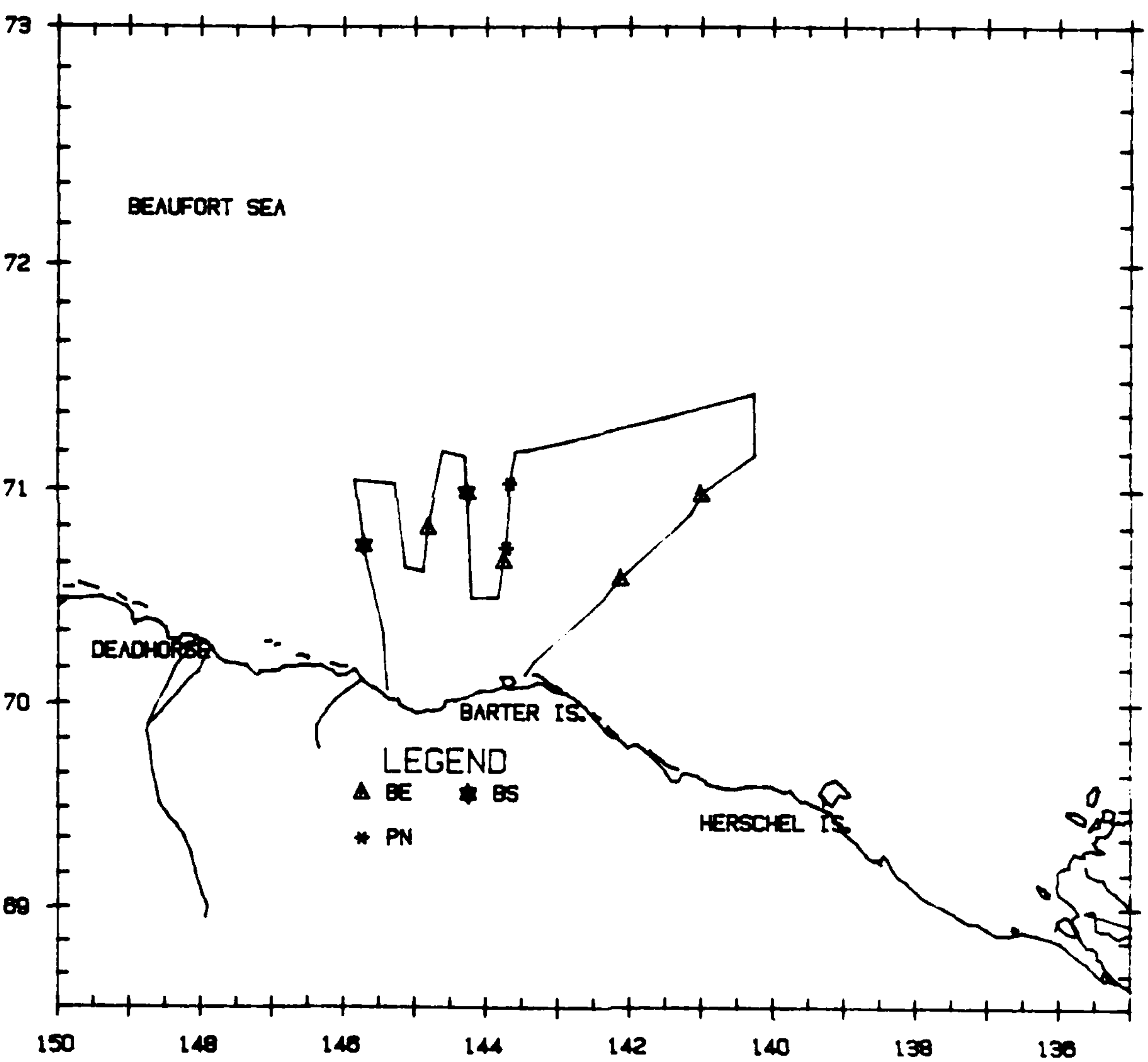
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°29.4'	140°21.6'	131	BW	SW	240	0	B6	474
1/0	70°26.4'	140°20.2'	207	BW	SW	290	0	B6	474
1/0	70°22.8'	140°20.7'	89	BW	SW	240	0	B6	64



73
72
71
70
69
150
148
146
144
142
140
138
136
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
PR
PN

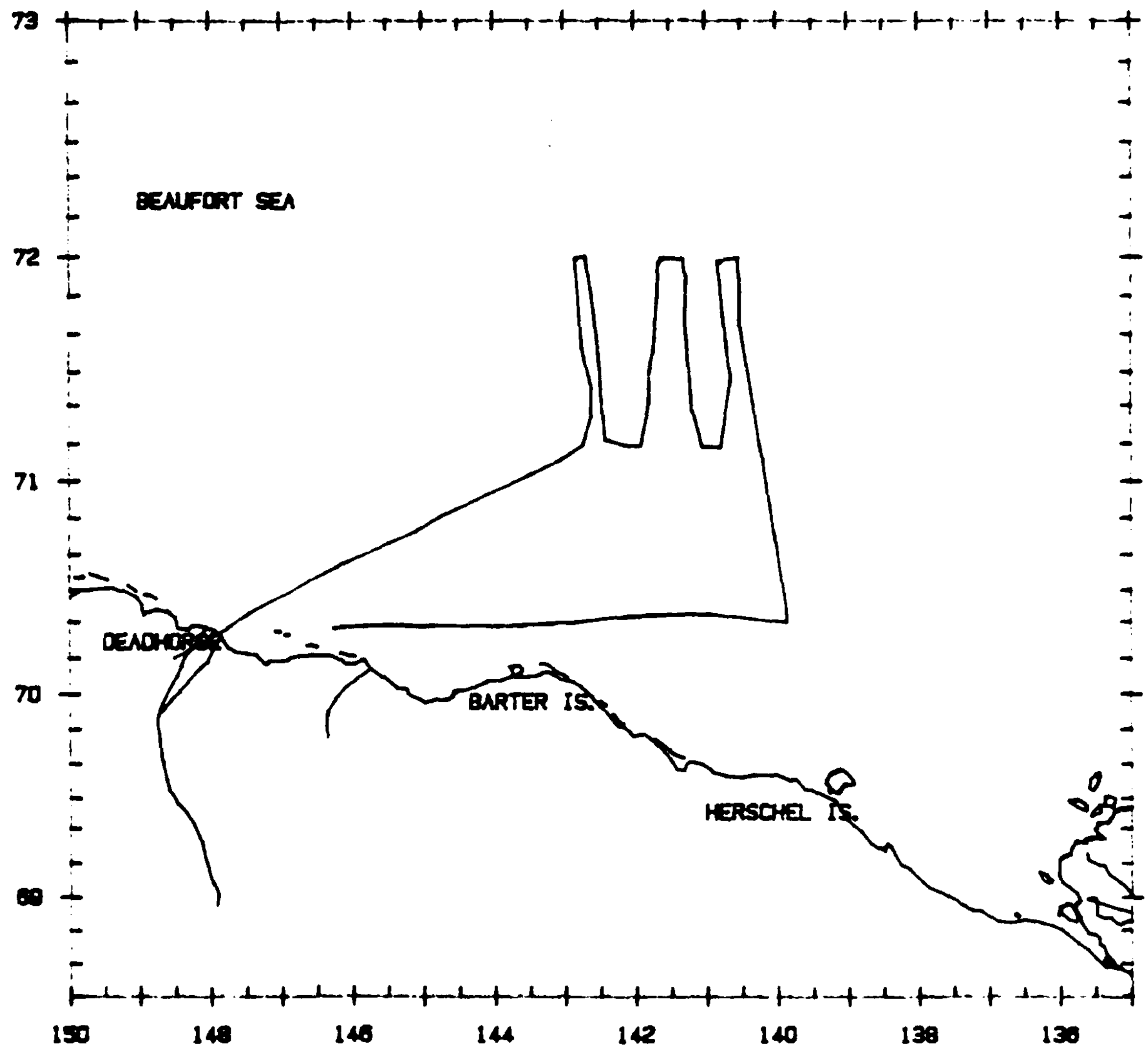
N780
Flight 4: 18 August 1986

Flight was a search survey through blocks 5 and 7 enroute to block 8 where a transect survey was aborted due to low heavy fog. A transect survey was completed in most of block 6 and along the westernmost leg in block 4. Visibility varied from 10 km to unacceptable. All blocks were nearly ice-free except block 6, where ice cover ranged from 30 to 75 percent in the northern half of the block. Sea state was Beaufort 01. Belukhas, bearded seals, and unidentified pinnipeds were seen.


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BE
BS
PN
150
148
146
144
142
140
138
136

N780
Flight 5: 19 August 1986

Flight was a transect survey of block 8 and a search survey across blocks 6 and 7, with a transect survey of the easternmost leg in block 7. Weather was partly cloudy with unlimited visibility. Ice cover ranged from open-water to approximately 40-percent cover in block 6, 95-percent cover in block 8 and 10-percent cover in block 7. Sea state varied from Beaufort 01 to 02 in areas with ice, to 05 to 06 in open water areas. No marine mammals were seen.



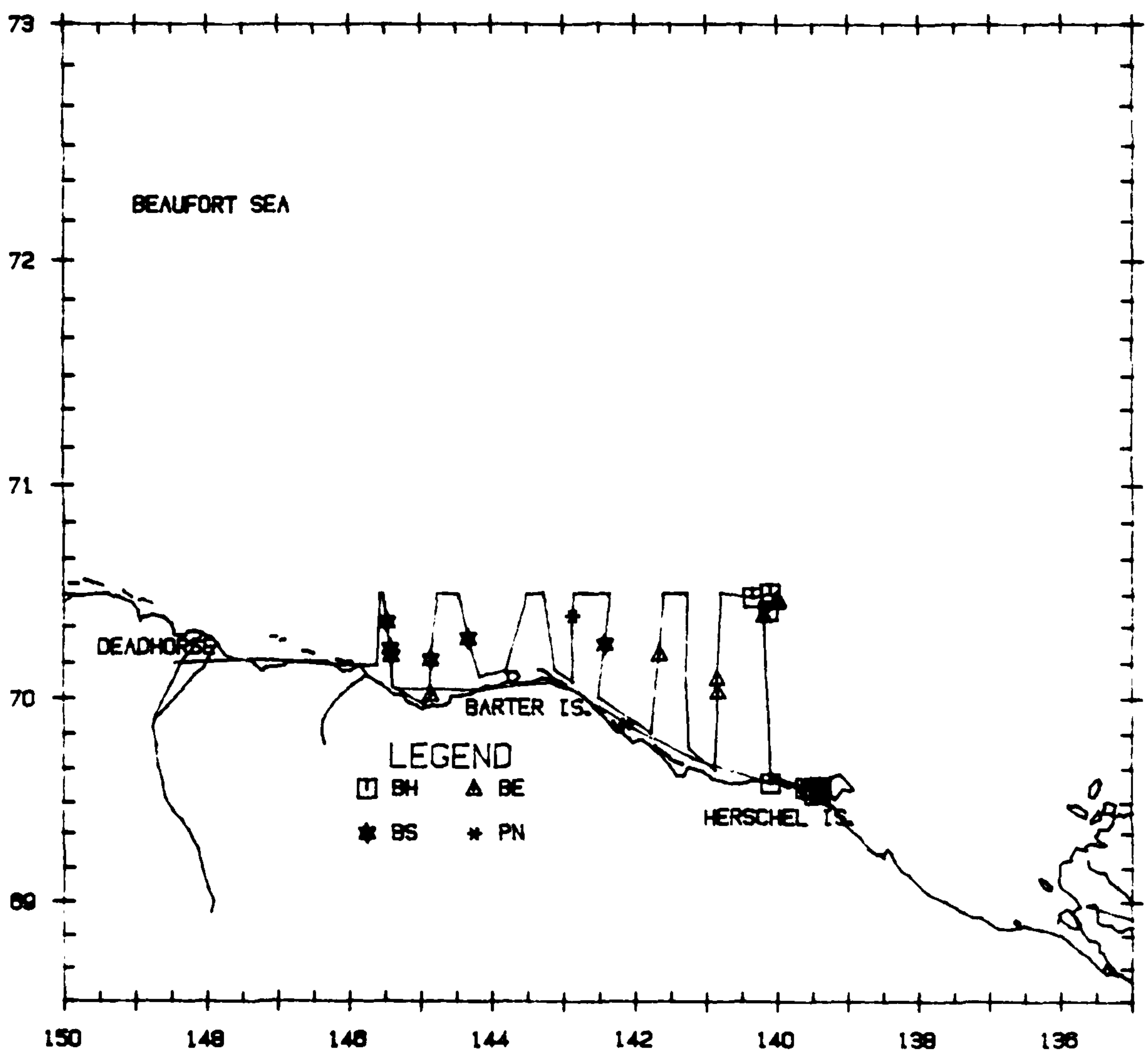
73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
150
148
146
144
142
140
138
136

N780
Flight 6: 20 August 1986

Flight was a transect survey of blocks 4 and 5 and a search survey east to Herschel Island. Weather was clear and visibility unlimited. Ice cover averaged 30 percent in block 4, 5 percent in block 5 and there was no ice in Canadian waters. Sea state was Beaufort 01 to 02. Twenty-four bowheads were seen, four in block 5 and 20 near Herschel Island. The whales nearshore were milling and feeding in murky light-green water. Belukhas, bearded seals, and unidentified pinnipeds were also seen.

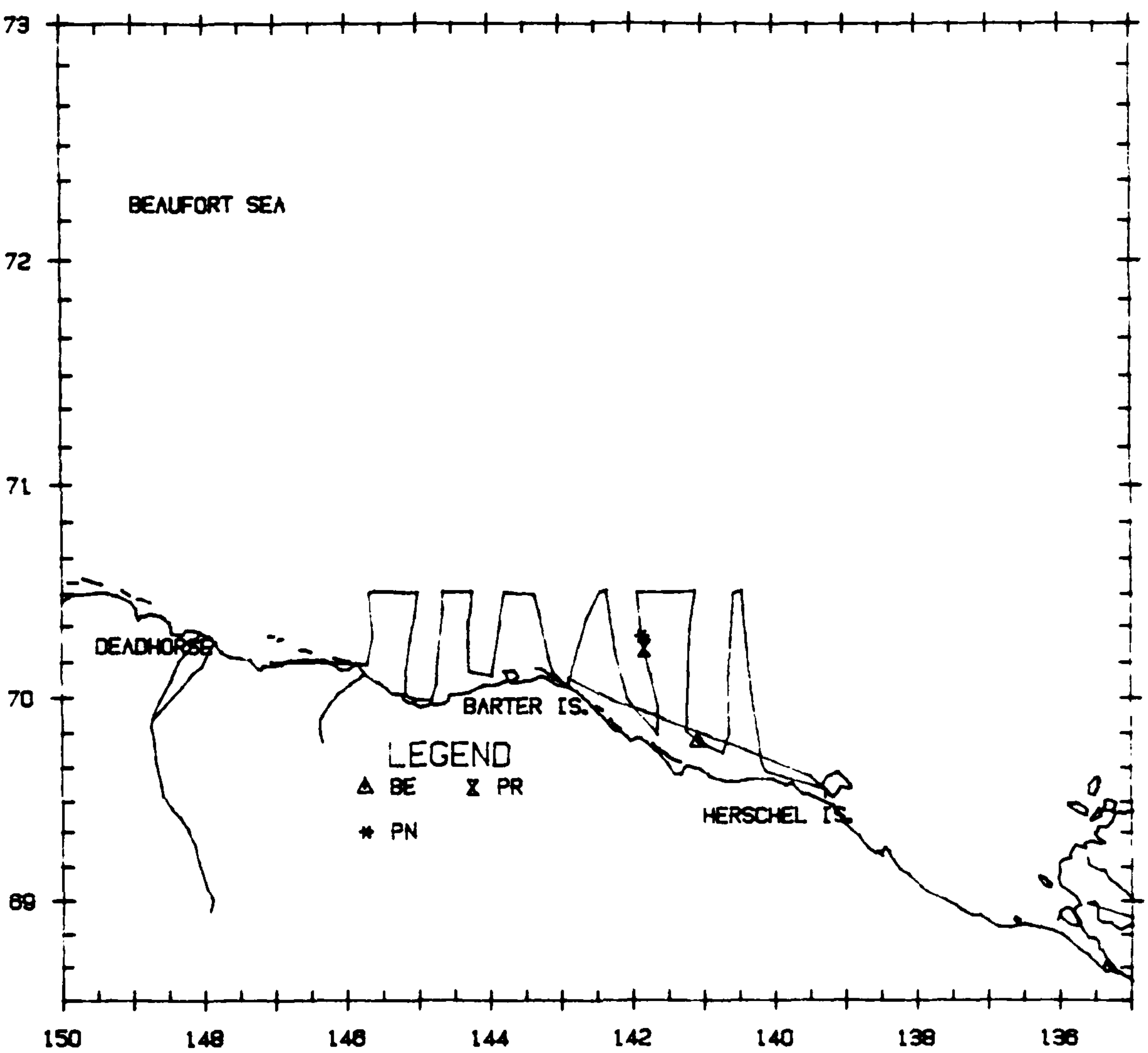
Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°28.2'	140°20.5'	508	BO	SW	150	0	B2	474
1/0	70°29.3'	140°05.5'	545	BO	RE	-	0	B2	505
1/0	70°24.6'	140°07.5'	-	BO	DI	150	0	B2	115
13/0	69°34.8'	139°35.7'	-	BW	FE	-	0	B1	5
3/1	69°34.4'	139°30.8'	-	BO	FE	-	0	B1	5
1/0	69°32.8'	139°28.0'	-	BO	MI	340	0	B1	5
1/0	69°32.8'	139°23.0'	-	BO	FE	-	0	B1	5
1/0	69°35.0'	139°23.5	-	BO	FE	-	0	B1	5
1/0	69°34.6'	139°22.1'	-	BO	FE	-	0	B1	5
1/0	69°36.1'	140°05.6'	-	SP	FE	-	0	B1	16


BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
BS
PN
73
72
71
70
69
150
148
146
144
142
140
138
136

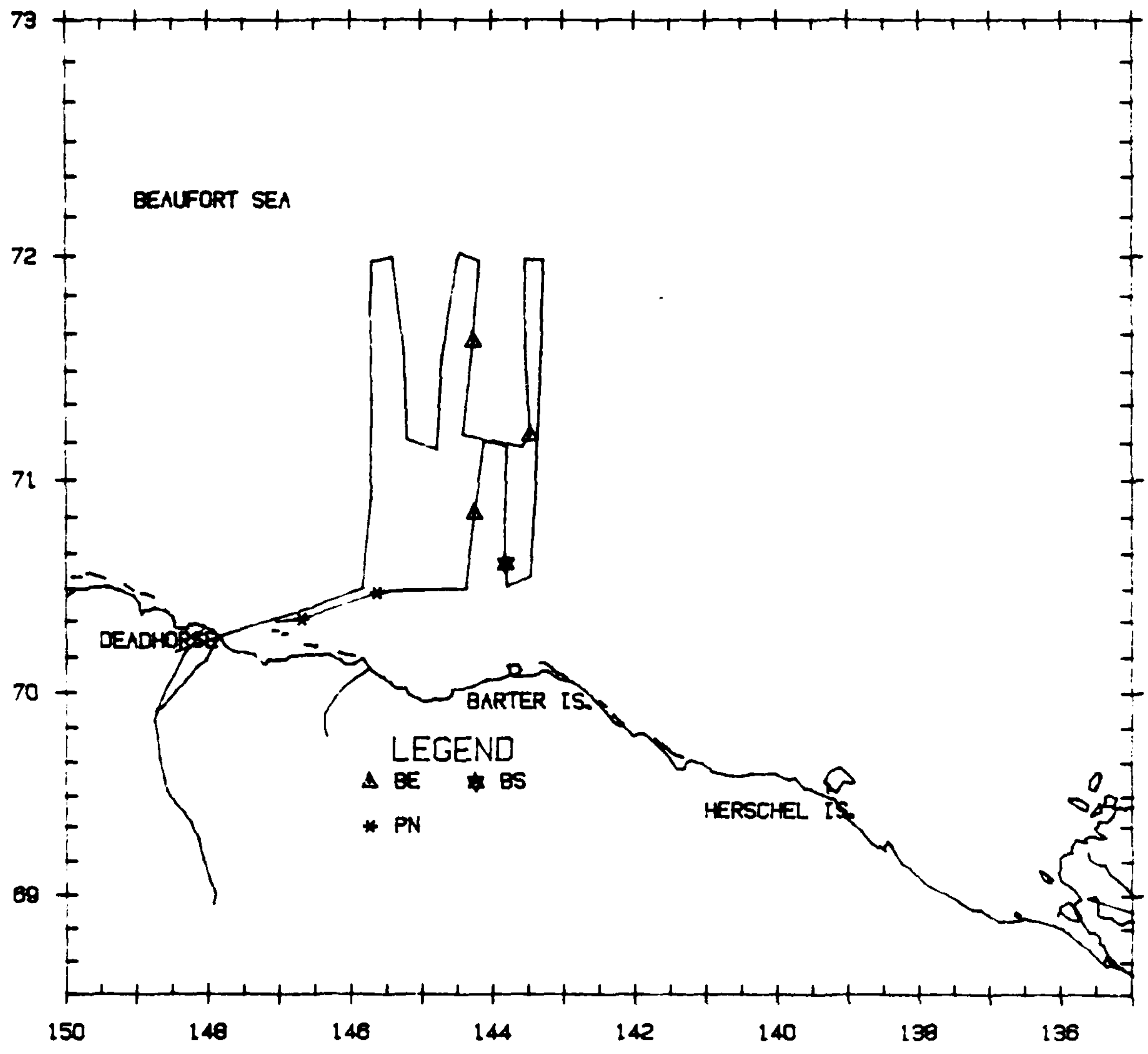
N780
Flight 7: 24 August 1986

Flight was a transect survey of blocks 4 and 5 and a search survey east to Herschel Island. Weather was low overcast with patches of fog and visibility varied from <1 to 10 km. Ice cover averaged 75 percent in block 4, 50 percent in block 5, and there was no ice in Canadian waters. Sea state ranged from Beaufort 01 to 05, but averaged 02. Belukhas, an unidentified pinniped, and a polar bear were seen.


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BE
PR
PN
150
148
146
144
142
140
138
136

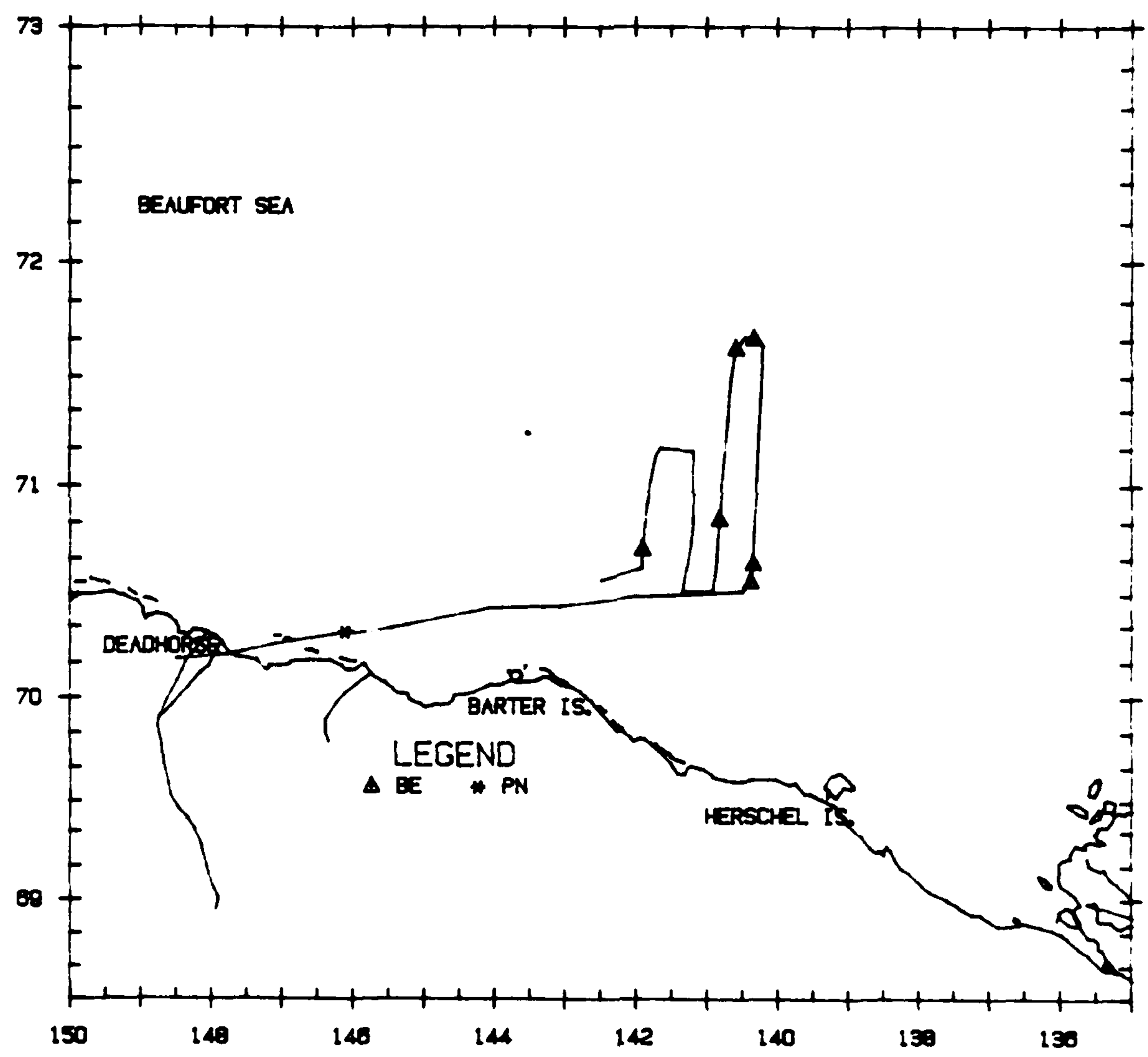
N780
Flight 8: 25 August 1986

Flight was a transect survey of block 9 and part of block 6. Weather was low overcast with patches of fog. Visibility varied from 1 to 10 km. Ice cover ranged from 30 to 95 percent in both blocks, with an average of 70 to 75 percent. Sea state ranged from Beaufort 01 to 02. Belukhas, a bearded seal, and unidentified pinnipeds were seen.


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BE
BS
PN
150
148
146
144
142
140
138
136

N780
Flight 9: 26 August 1986

Flight was a search survey through blocks 4 and 5 and a transect survey of portions of blocks 7 and 8. Weather was low overcast with patches of fog. Visibility varied from < 1 to 10 km. Ice cover was approximately 70 percent in block 4, 50 percent in block 5, 40 percent in block 7 and 60 percent in block 8. Sea state was Beaufort 01 to 02. Belukhas and an unidentified pinniped were seen.

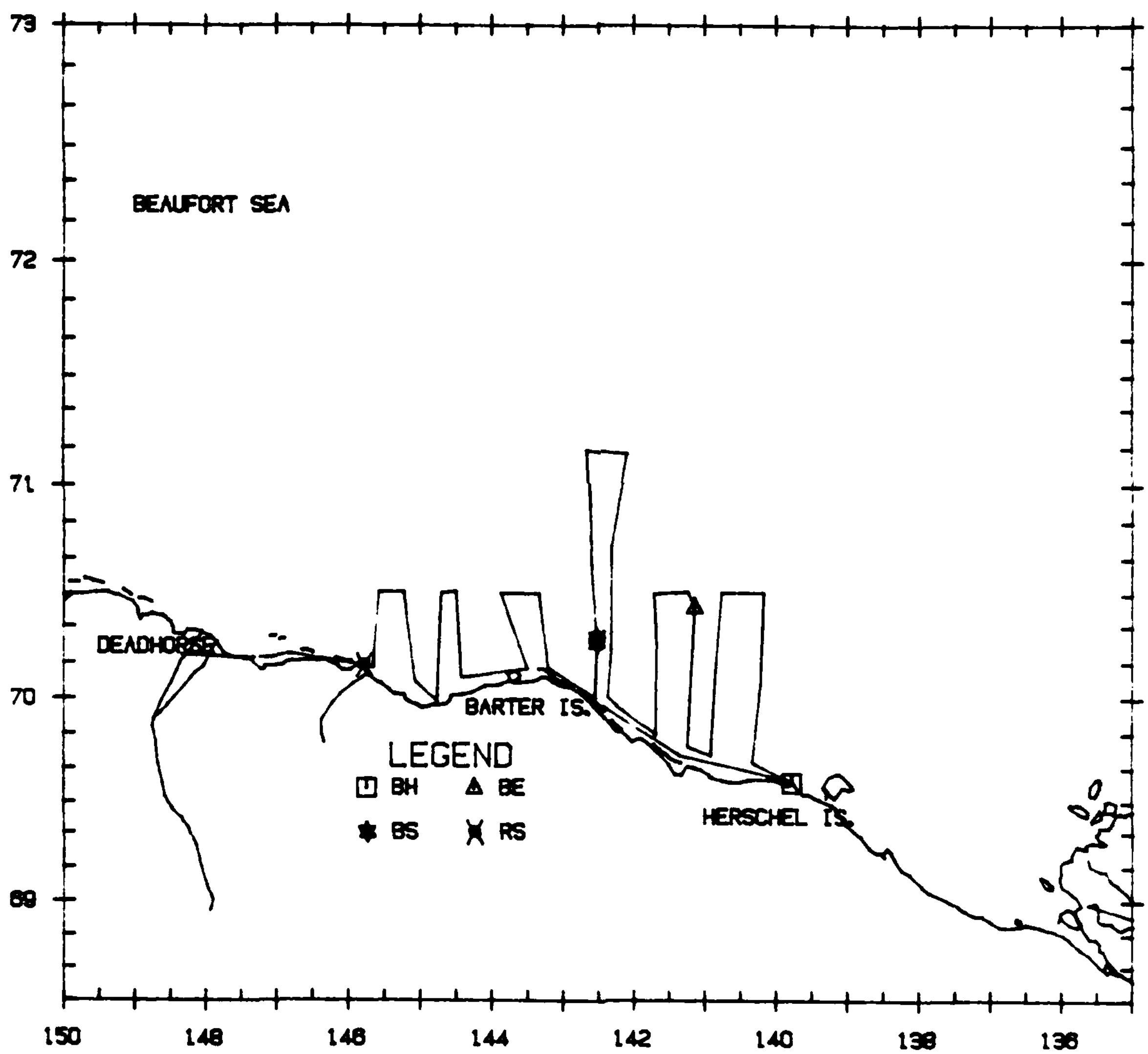

73
72
71
70
69
150
148
146
144
142
140
138
136
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
▲ BE
* PN

N780
Flight 10: 28 August 1986

Flight was a transect survey of blocks 4, 5 and the western one-third of block 7, with a search survey along the Canadian coast to Herschel Island. Weather was low overcast with patchy fog. Visibility varied from 1 to 10 km. Ice cover was approximately 40 percent in block 4, 20 percent in block 5, 30 percent in block 7 and Canadian waters were ice-free. Sea state ranged from Beaufort 01 to 05, but averaged 02. One bowhead was seen nearshore approximately 35 km west of Herschel Island. A belukha, bearded seals, and a ringed seal were also seen.

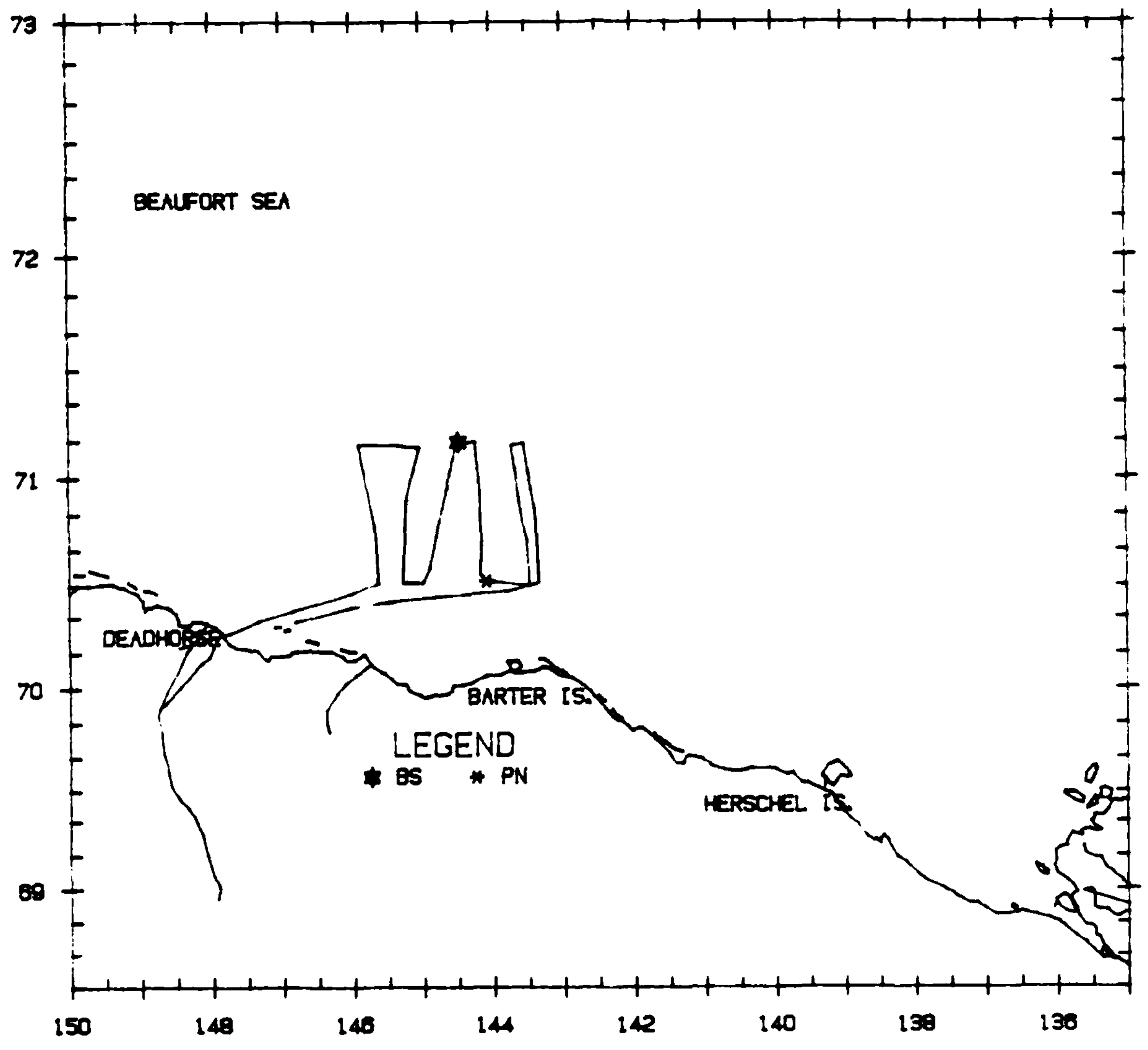
Bowhead Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°35.9'	139°46.4'	-	BO	SW	90	0	B3	15


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
BS
RS
150
148
146
144
142
140
138
136

N780
Flight 11: 29 August 1986

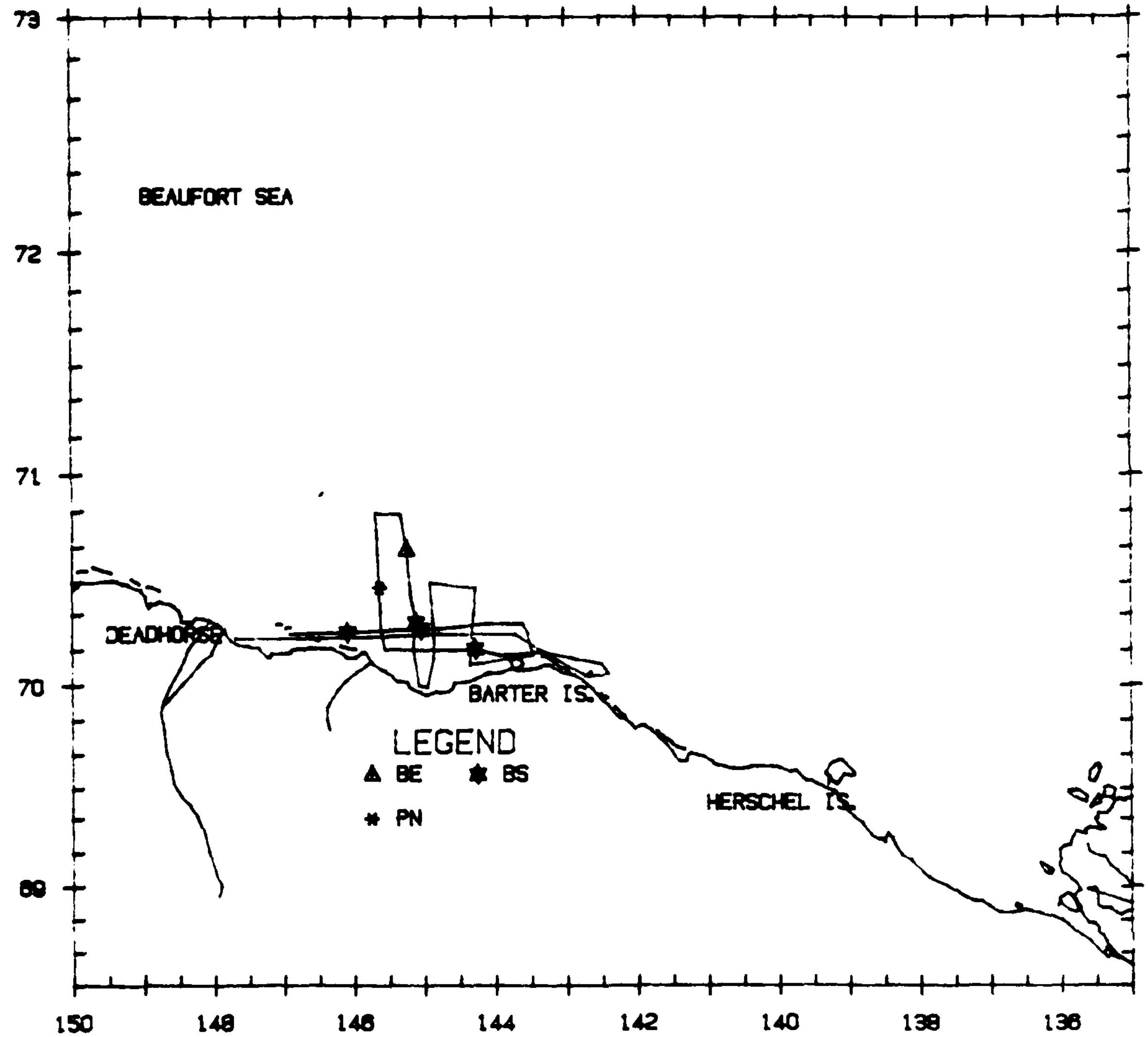
Flight was a transect survey of block 6, with a search survey across block 4. Weather was partly cloudy and visibility varied from 5 km to unlimited. Ice cover was approximately 40 percent in block 6 and roughly 20 percent in block 4. Sea state ranged from Beaufort 02 to 08, but averaged 03. Bearded seals and an unidentified pinniped were seen.



73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BS
PN
150
148
146
144
142
140
138
136

N780
Flight 12: 31 August 1986

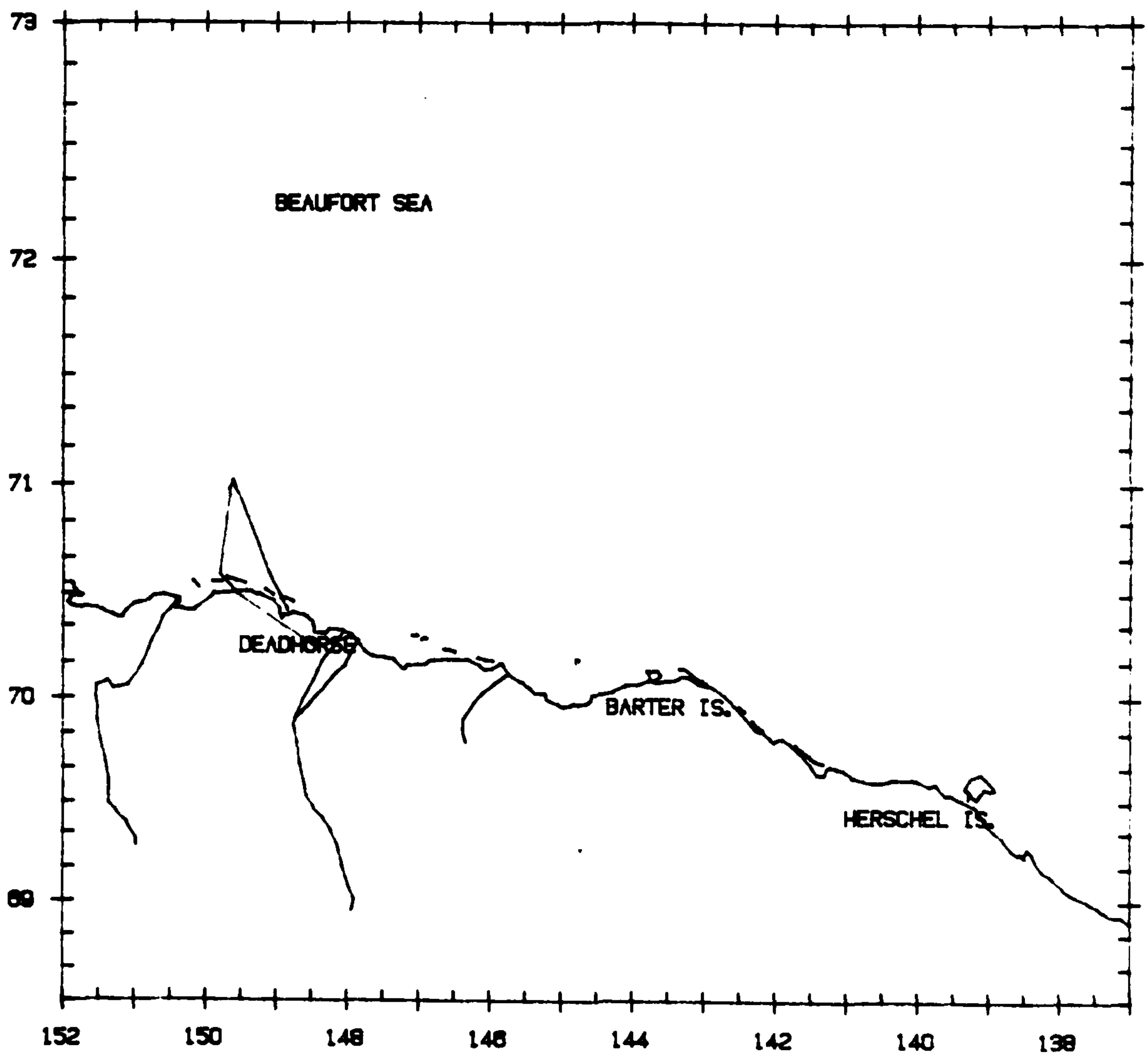
Flight was an attempted transect survey of block 5, then blocks 4 and 6. Transect legs in all blocks had to be truncated or aborted, due to heavy low-lying fog. Visibility varied from <1 km to 10 km. Ice cover was approximately 10 percent in blocks 4 and 5, and about 20 percent in block 6. Sea state ranged from Beaufort 00 to 02. Belukhas, bearded seals, and an unidentified pinniped were seen.



73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
▲ BE
✱ BS
✱ PN
150
148
146
144
142
140
138
136

N780
Flight 13: 1 September 1986

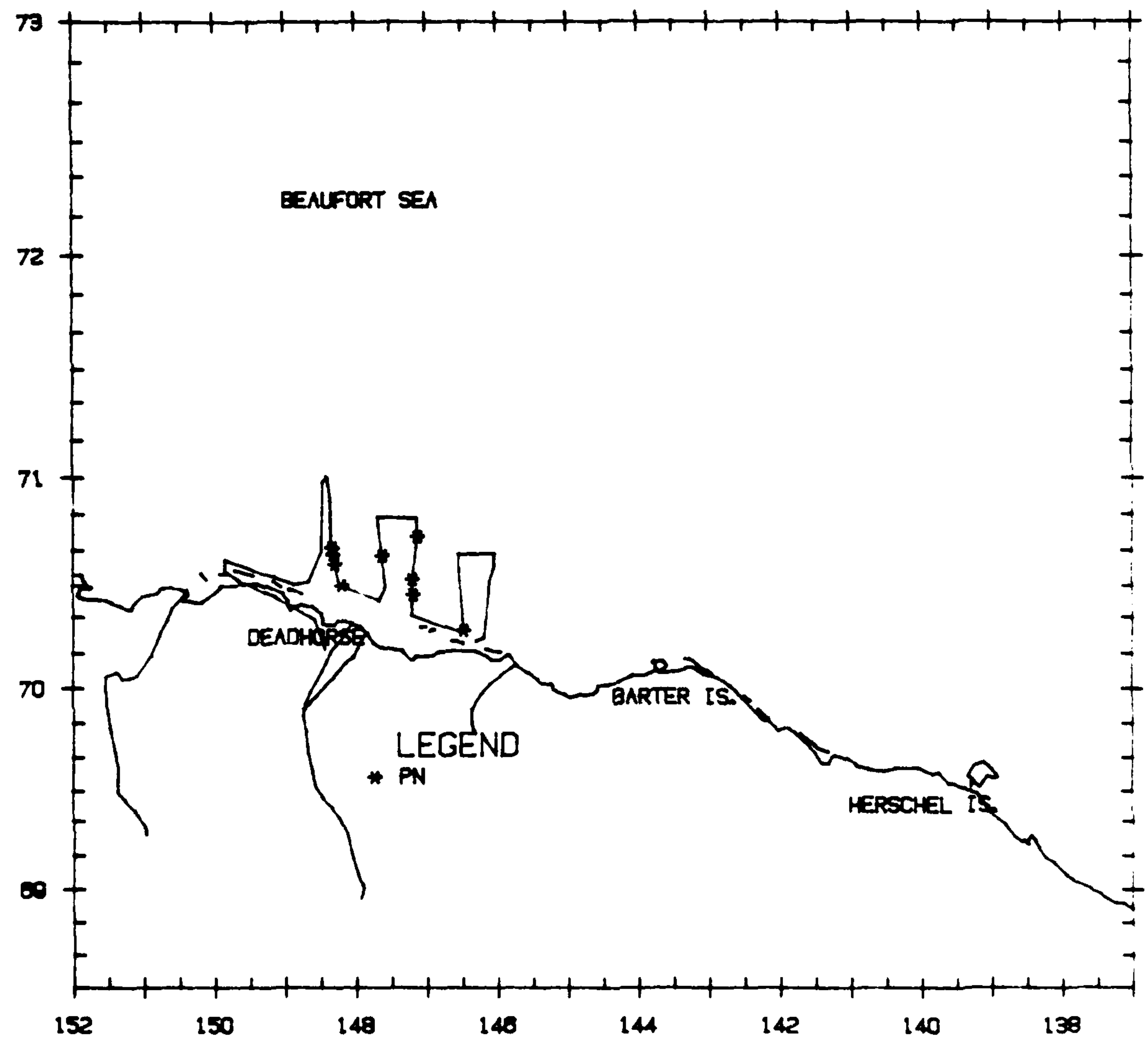
Flight was an aborted transect survey of block 1. Dense, low-lying fog that blanketed all areas within visual range at an altitude of 7400 m prevented surveying any alternate block. There were no sightings.



73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
152
150
148
146
144
142
140
138

N780
Flight 14: 2 September 1986

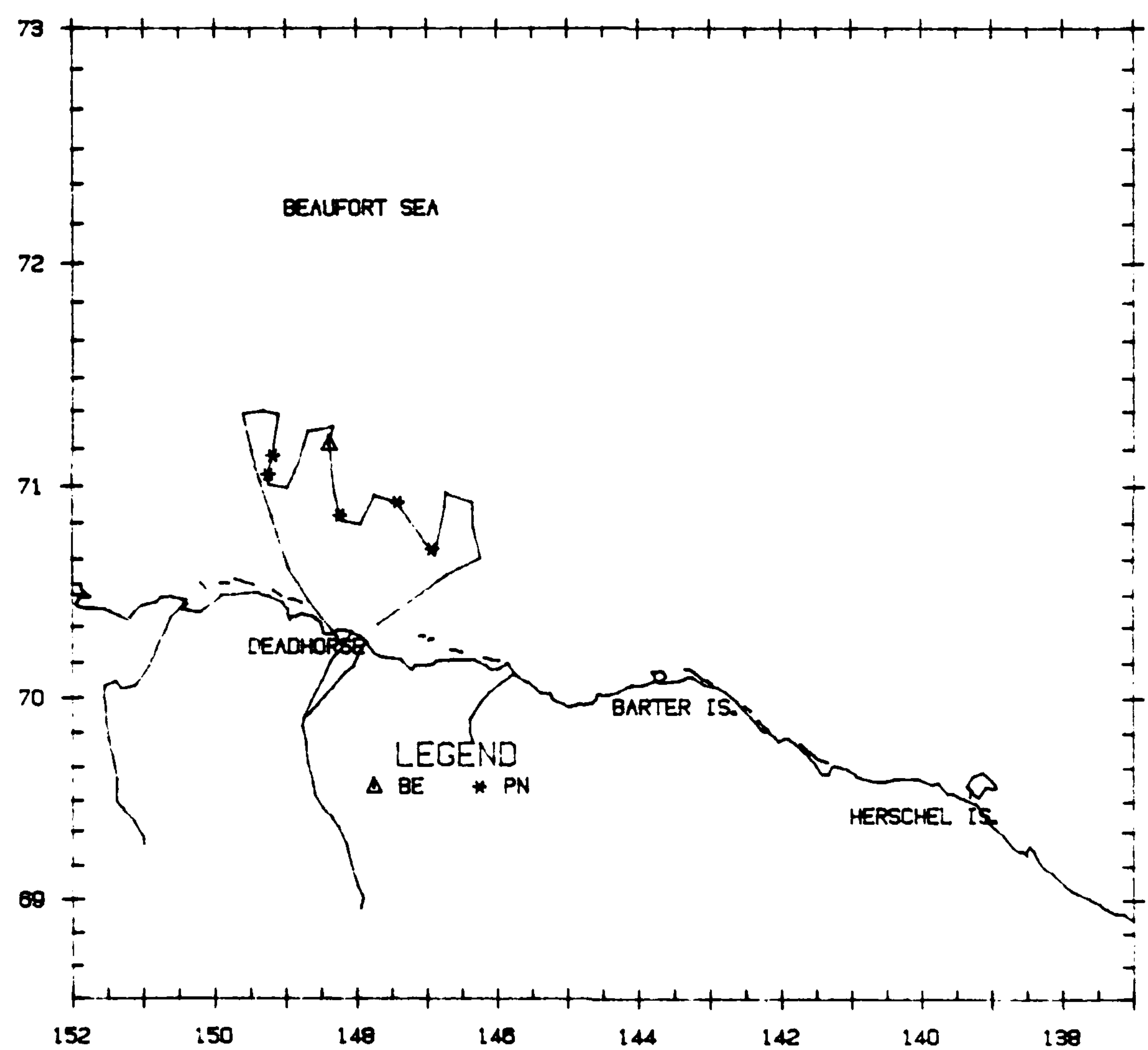
Flight was a transect survey of the eastern three-quarters of block 1. Except for the westernmost portion of block 1 where low dense fog precluded surveying, weather was partly cloudy with unlimited visibility. Sea state was Beaufort 01 to 02. Unidentified pinnipeds were the only marine mammals seen.



73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
* PN
152
150
148
146
144
142
140
138

N780
Flight 15: 2 September 1986

Flight was a transect survey of the southern one-half of block 2. Low-lying fog precluded flying in the northern half of the block but visibility was unlimited in the southern half. Ice cover was 10- to 30-percent broken floe and sea state was Beaufort 01. Belukhas and unidentified pinnipeds were seen.



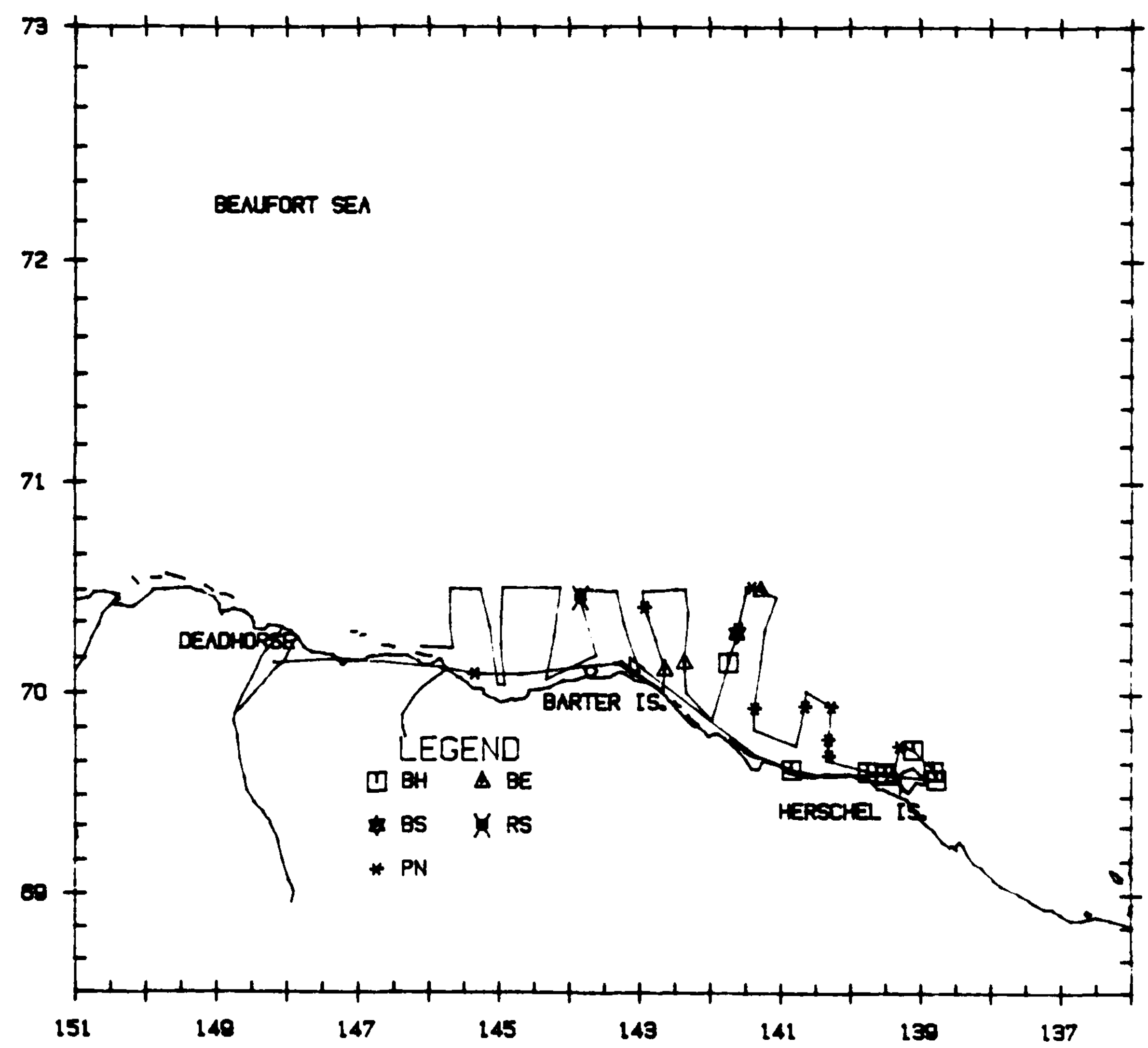
73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
Δ BE
* PN
152
150
148
146
144
142
140
138

N780
Flight 16: 3 September 1986

Flight was a transect survey of block 4 and the western two-thirds of block 5 with a search survey to Herschel Island. Low-lying fog caused the easternmost two transect legs in block 5 to be truncated. Weather was clear and visibility was unlimited. Ice cover was 0 to 10 percent in block 4 and there was no ice in block 5. Sea state was Beaufort 01 to 02. Sixteen bowheads were seen, three in block 5 and thirteen in Canada between Herschel Island and Komakuk. Belukhas, a bearded seal, a ringed seal, and unidentified pinnipeds were also seen.

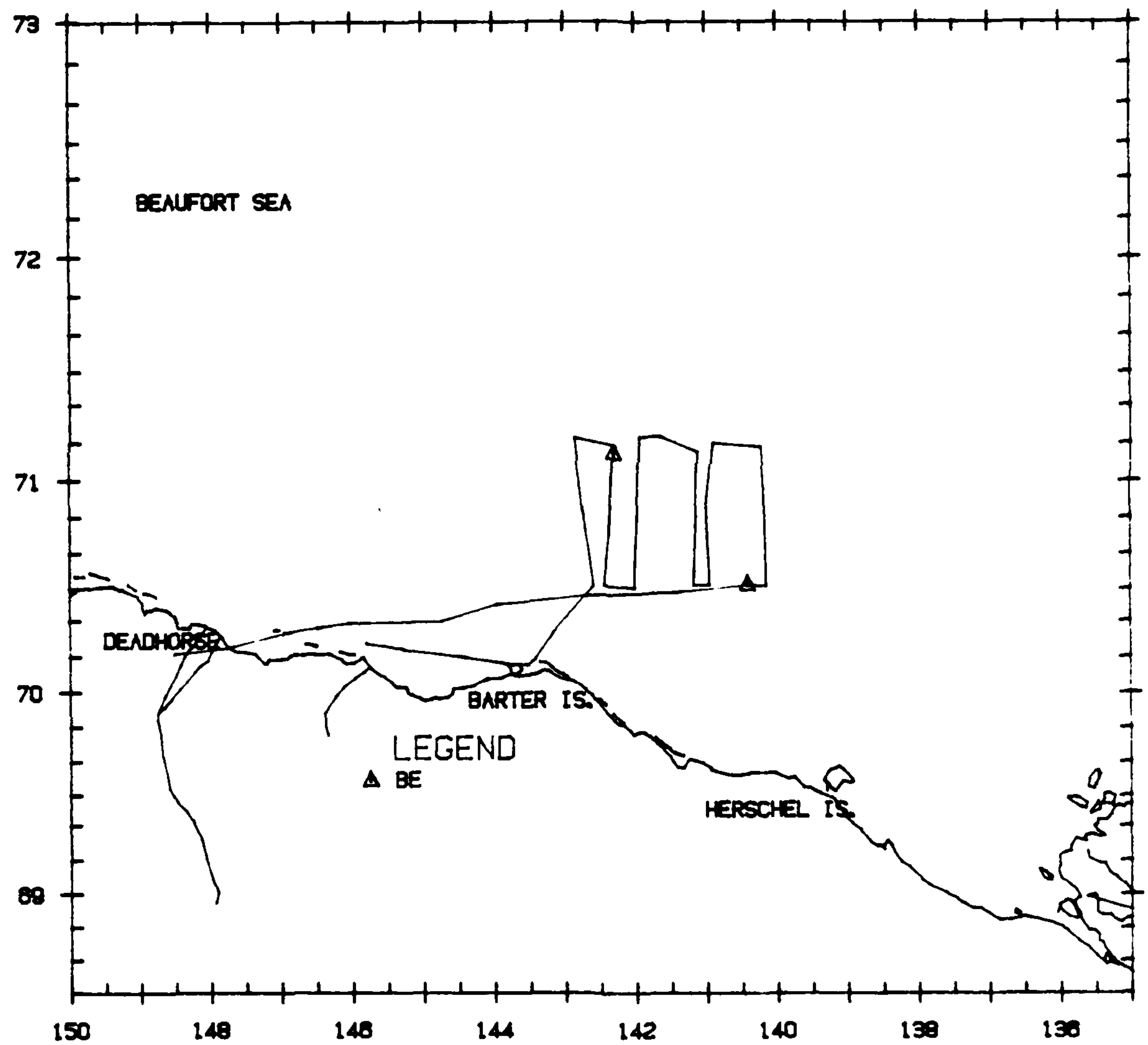
Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°09.1'	141°44.4'	607	BO	SW	330	0	B2	38
4/0	69°37.5'	139°45.6'	1094	SP	SW	120	0	B2	15
2/0	69°37.2'	139°30.3'	-	SP	BR	120	0	B2	16
1/0	69°44.1'	139°06.6'	-	BW	SW	120	0	B2	18
3/0	69°37.8'	138°49.3'	518	BO	FE	-	0	B2	77
2/0	69°35.3'	138°46.9'	555	BO	SW	240	0	B2	77
1/0	69°36.8'	139°30.8'	-	BW	SW	360	0	B2	16
2/0	69°38.3'	140°51.2'	1013	BO	FE	250	0	B2	7


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
BS
RS
PN
151
149
147
145
143
141
139
137

N780
Flight 17: 4 September 1986

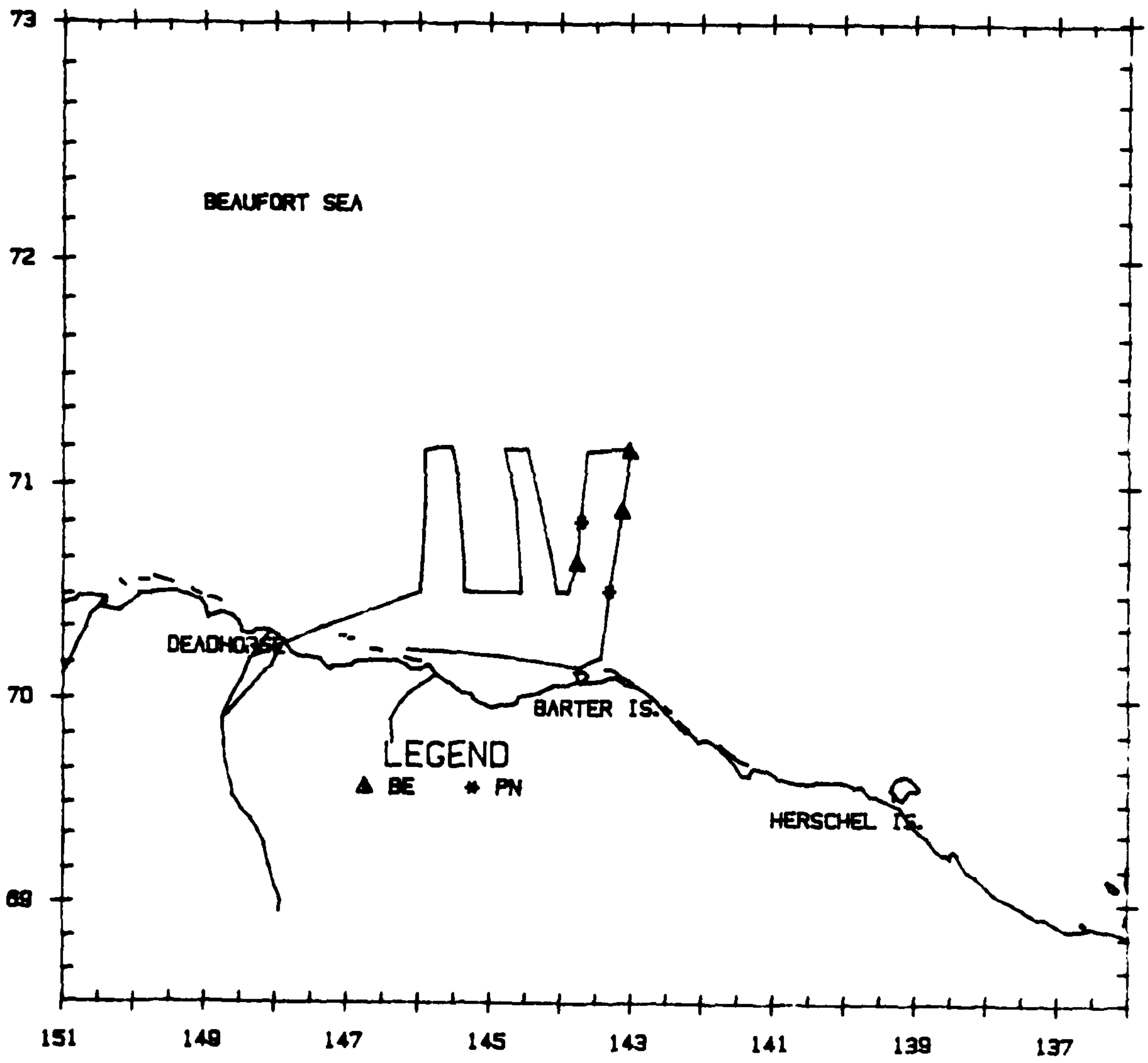
Flight was a transect survey of block 7. Weather was overcast with unlimited visibility. Sea state was Beaufort 01 to 02 and there was no ice. Belukhas were the only marine mammals seen.



73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BE
150
148
146
144
142
140
138
136

N780
Flight 18: 5 September 1986

Flight was a transect survey of block 6. Weather was overcast with unlimited visibility. Ice cover was 0 to 20 percent and sea state was Beaufort 01 to 02. Belukhas and unidentified pinnipeds were seen.

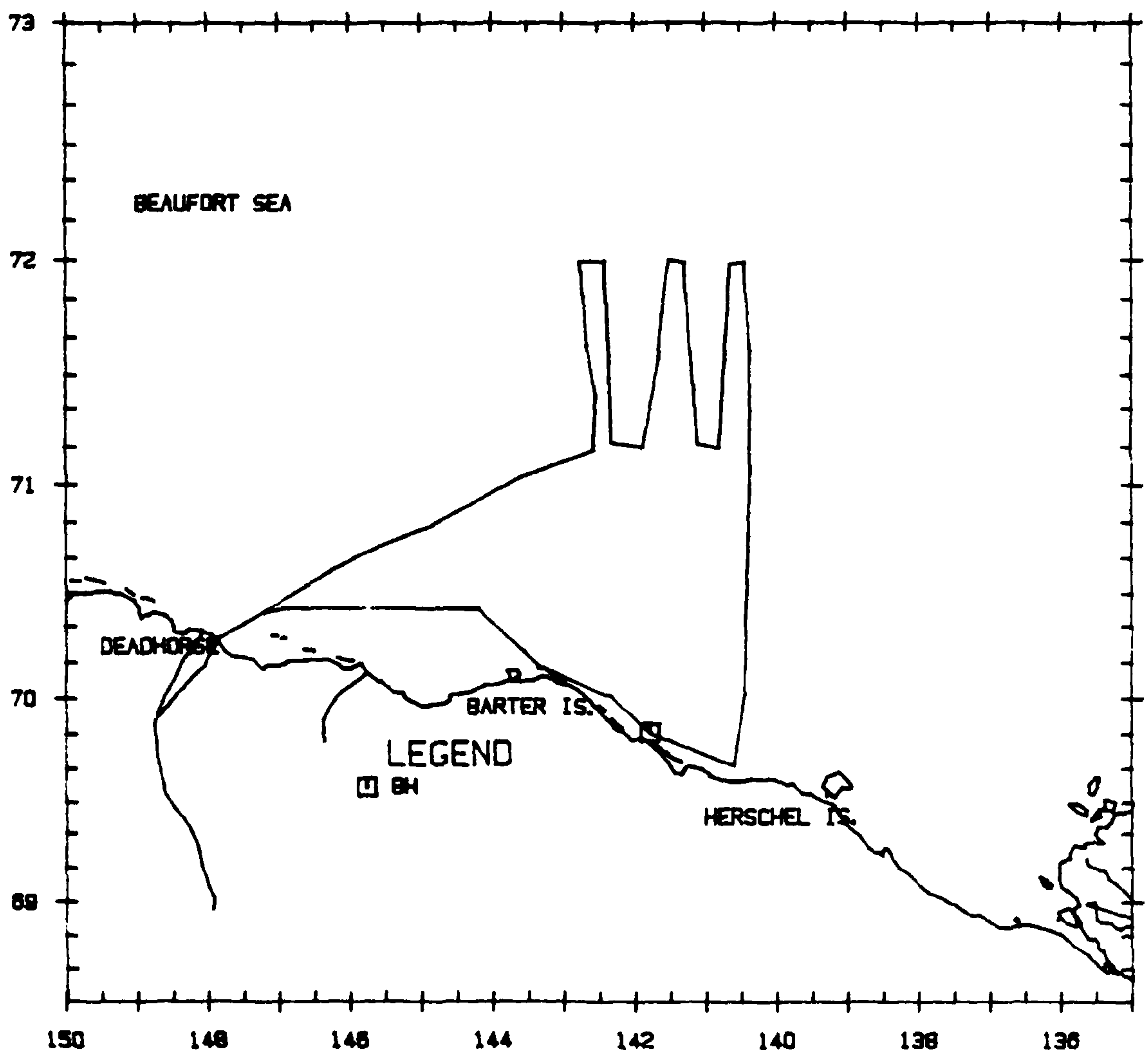

73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
▲ BE * PN
151
149
147
145
143
141
139
137

N780
Flight 19: 6 September 1986

Flight was a transect survey of block 8. Weather was clear with unlimited visibility. Ice cover was 0 to 5 percent in all but the northern corner where it was 95- to 99-percent broken floe. Sea state was Beaufort 00 to 04. Five bowheads were seen during a coastal transit back to Deadhorse. No other marine mammals were seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
5/0	69°50.2'	141°46.8'	-	BW	FE	-	0	B2	18


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
150
148
146
144
142
140
138
136

N780
Flight 20: 7 September 1986

Flight was a transit through blocks 3, 12, and 13 and a transect survey of block 14. Weather was clear and visibility was unlimited. Sea state ranged from Beaufort 02 to 05 and there was no ice. Sixty-six gray whales were seen north and west of Point Barrow, including one group of three engaged in mating behavior. Walrus, unidentified pinnipeds, a bearded seal, and a belukha were also seen.

Gray Whales

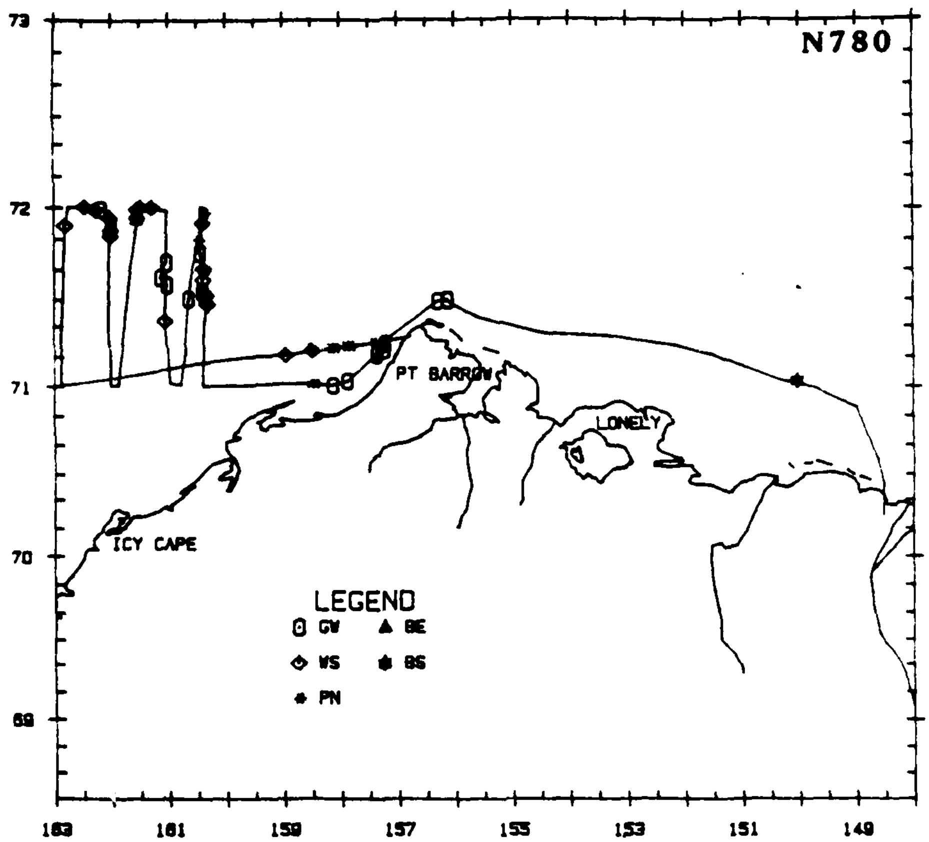
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	71°28.3'	156°07.5'	-	MP	FE	-	0	B2	9
3/0	71°28.6'	156°07.5'	-	MP	FE	-	0	B2	9
13/1	71°28.0'	156°18.0'	-	MP	FE	-	0	B2	9
6/0	71°14.2'	157°12.9'	-	MP	FE	-	0	B2	18
2/0	71°12.0'	157°14.0'	-	MP	FE	-	0	B2	18
3/0	71°12.0'	157°21.6'	-	SP	MT	-	0	B2	38
1/0	71°10.6'	157°22.2'	-	BO	FE	-	0	B2	38
1/0	71°01.8'	157°52.2'	-	BO	SW	220	0	B2	27
1/0	71°00.3'	158°07.5'	1981	BO	SW	-	0	B2	20
6/0	71°30.9'	160°21.6'	1013	MP	FE	-	0	B3	42
4/0	71°32.6'	160°24.6'	-	MP	FE	-	0	B3	42
1/0	71°45.4'	160°26.7'	1650	BO	DI	-	0	B3	49
1/0	71°30.3'	160°39.0'	1650	BW	FE	-	0	B3	42
2/0	71°34.9'	161°01.8'	938	BO	RE	-	0	B3	42
1/0	71°37.3'	161°08.4'	-	BO	BR	-	0	B3	38
7/0	71°42.3'	161°01.8'	1834	BW	FE	-	0	B3	38
8/0	71°54.1'	162°00.0'	320	MP	FE	-	0	B3	33
3/0	71°59.3'	162°10.5'	1056	MP	FE	-	0	B3	33

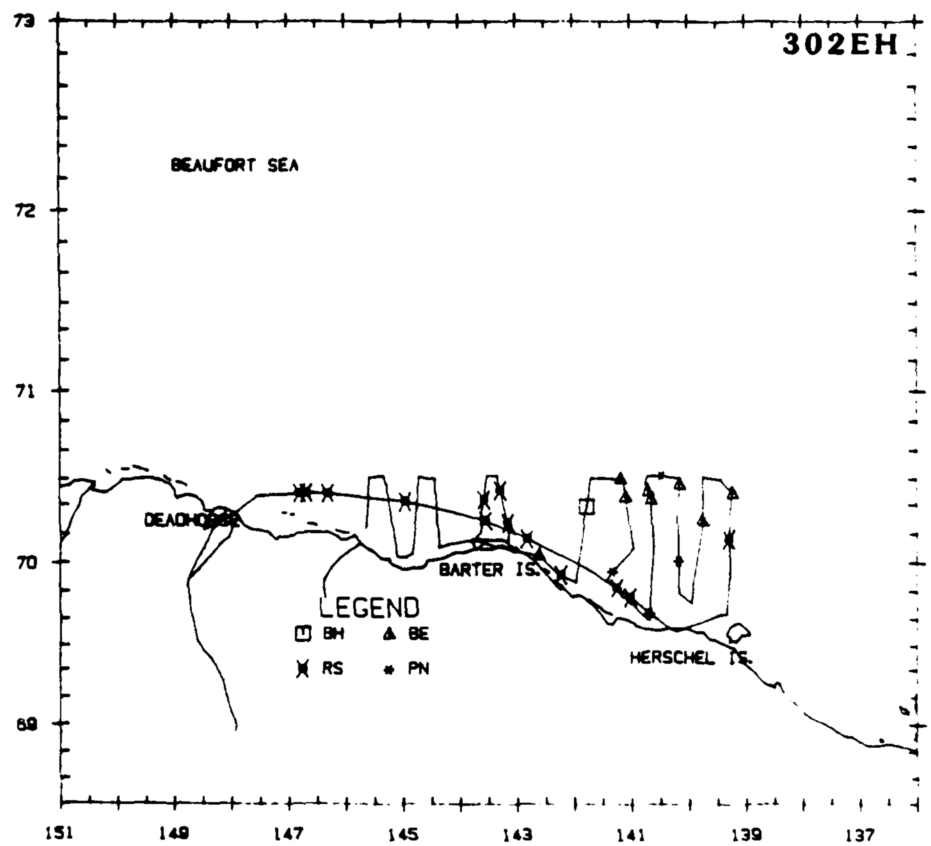
302 EH
Flight 1: 7 September 1986

Flight was a transect survey of blocks 4 and 5. Weather was partly cloudy with unlimited visibility. Ice cover was generally 0 percent with localized areas of up to 35-percent cover. Sea state ranged from Beaufort 01 to 03. One bowhead was seen swimming slowly west. Belukhas, ringed seals, and unidentified pinnipeds were also seen.

Bowhead Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°19.3'	141°46.0'	183	BW	SW	270	0	B2	51


N780
PT BARROW
LONELY
ICY CAPE
LEGEND
GV
BE
WS
BG
PN
73
72
71
70
69
163
161
159
157
155
153
151
149

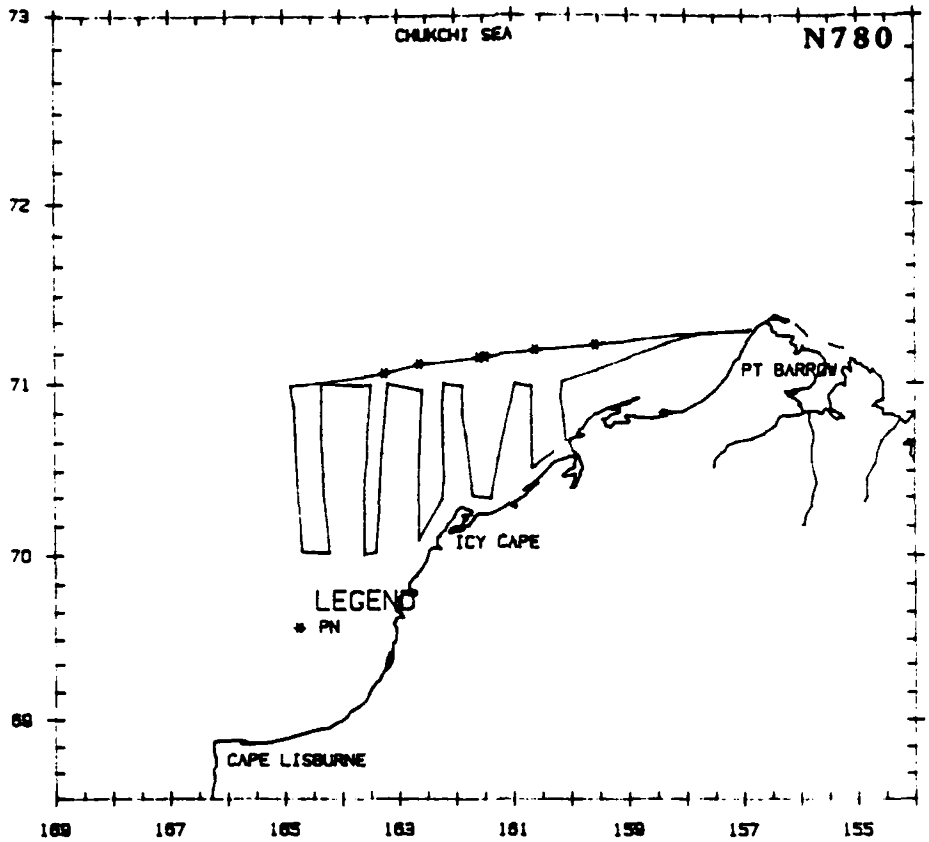

302EH
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
RS
PN
73
72
71
70
69
151
149
147
145
143
141
139
137

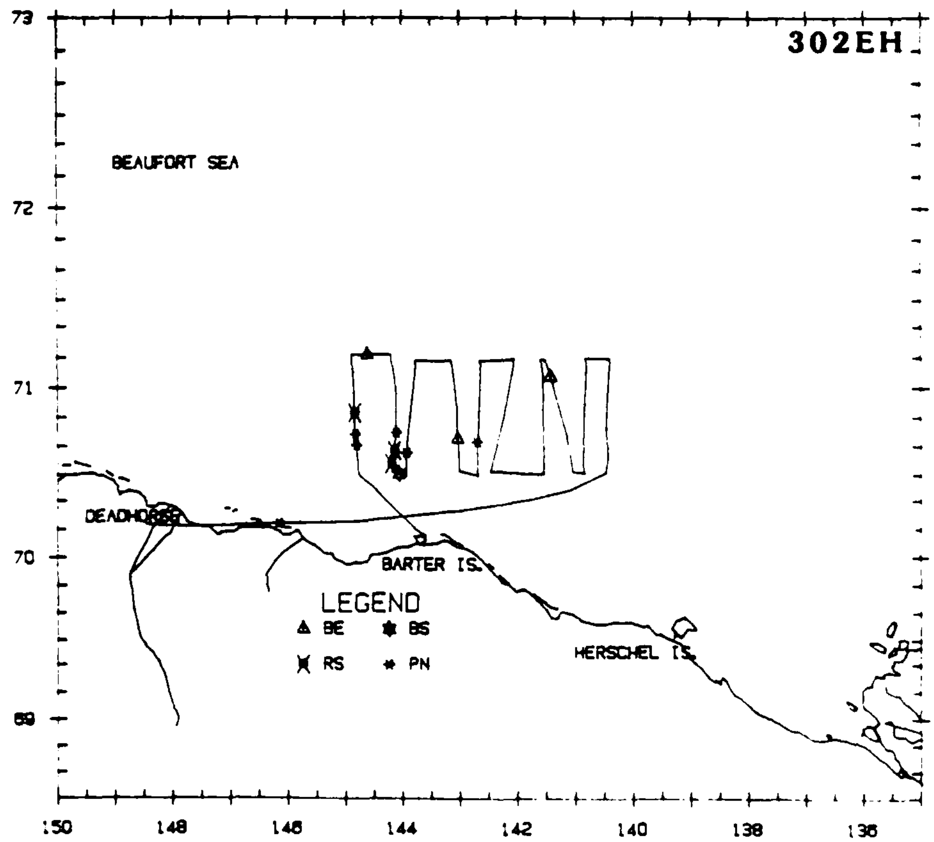
N780
Flight 21: 9 September 1986

Flight was a transect survey of block 17 and the western two-thirds of block 18. Weather was low overcast with intermittent snow squalls. Sea state ranged from Beaufort 03 to 05 and there was no ice. Unidentified pinnipeds were the only marine mammals seen.

302 EH
Flight 2: 9 September 1986

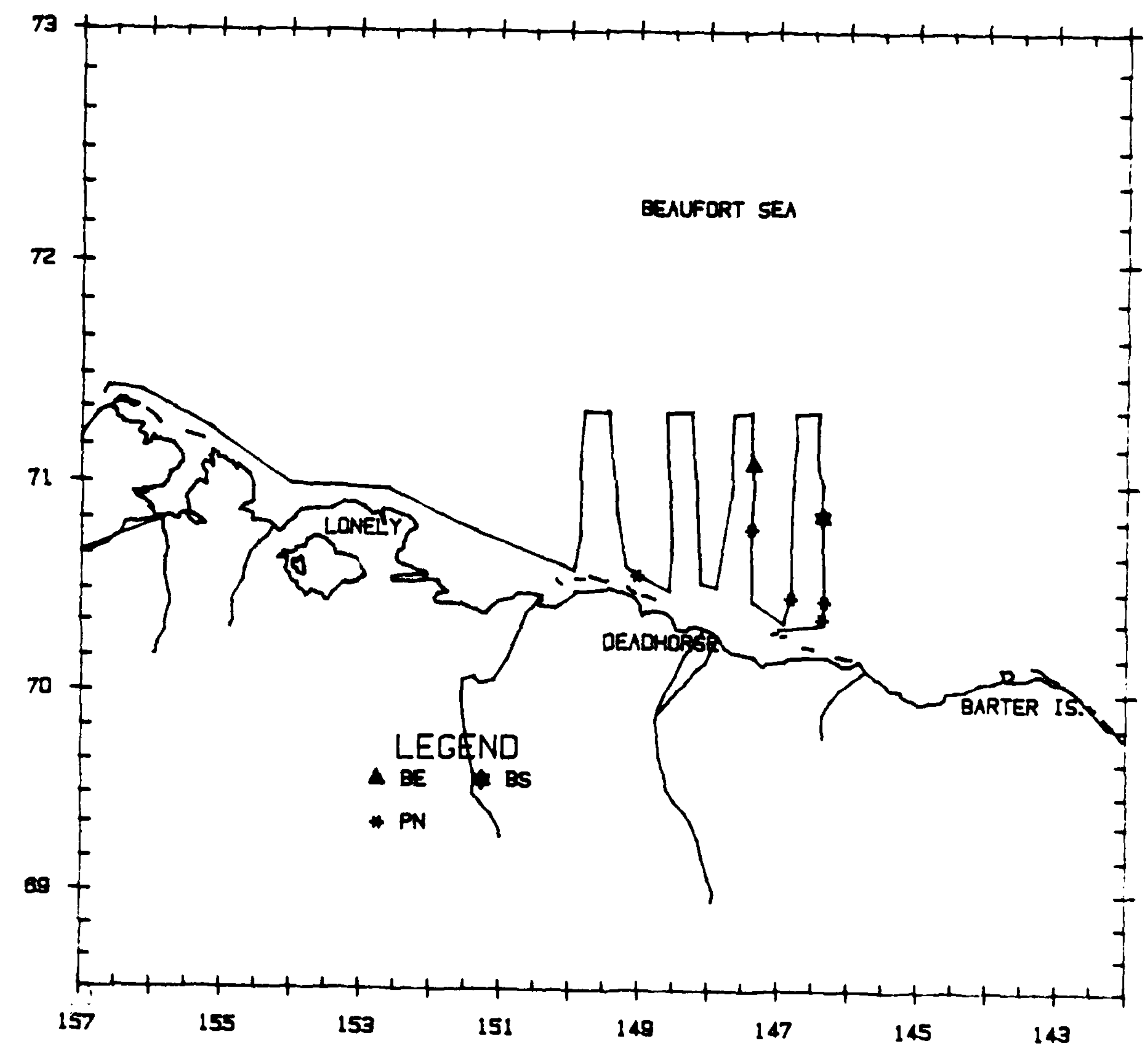
Flight was a transect survey of block 7 and the eastern two-thirds of block 6. Weather was overcast with some patchy fog in block 7. Visibility varied from 1 km to unlimited. Ice cover was generally 0 percent, with localized areas of block 6 ranging to 50-percent cover. Sea state was Beaufort 01 to 04. Belukhas, bearded seals, ringed seals, and unidentified pinnipeds were seen.


73
CHUKCHI SEA
N780
72
PT BARROW
71
ICY CAPE
70
LEGEND
PN
CAPE LISBURNE
169
167
165
163
161
159
157
155


73
302EH
BEAUFORT SEA
72
71
DEADHORSE
70
BARTER IS.
LEGEND
BE
BS
RS
PN
HERSCHEL IS.
69
150
148
146
144
142
140
138
136

N780
Flight 22: 10 September 1986

Flight was a transect survey of blocks 1 and 2. Weather was clear with unlimited visibility. Ice cover was 0 to 30 percent in block 1 and 0 to 70 percent in block 2. Sea state was Beaufort 01 to 05. Belukhas, bearded seals, and unidentified pinnipeds were seen.

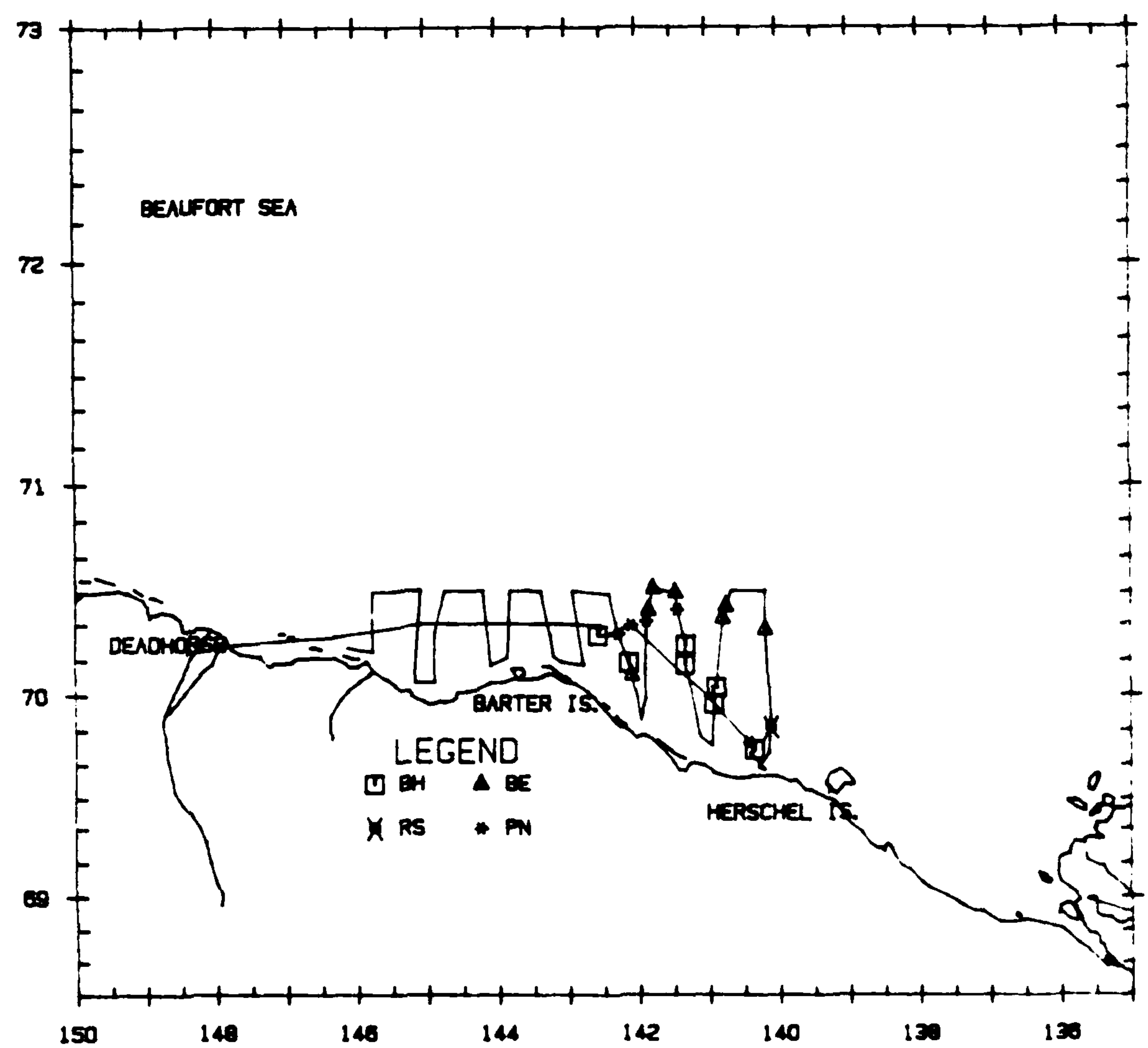

73
72
71
70
69
157
155
153
151
149
147
145
143
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
LEGEND
BE
BS
PN

N780
Flight 23: 11 September 1986

Flight was a transect survey of blocks 4 and 5. Weather was clear and visibility unlimited. Ice cover varied from 0 to 10 percent in block 4 and there was no ice in block 5. Sea state was Beaufort 01 to 02. Eight bowheads were seen in block 8; the whale farthest west was playing with a log when first sighted. Belukhas, ringed seals, and unidentified pinnipeds were also seen.

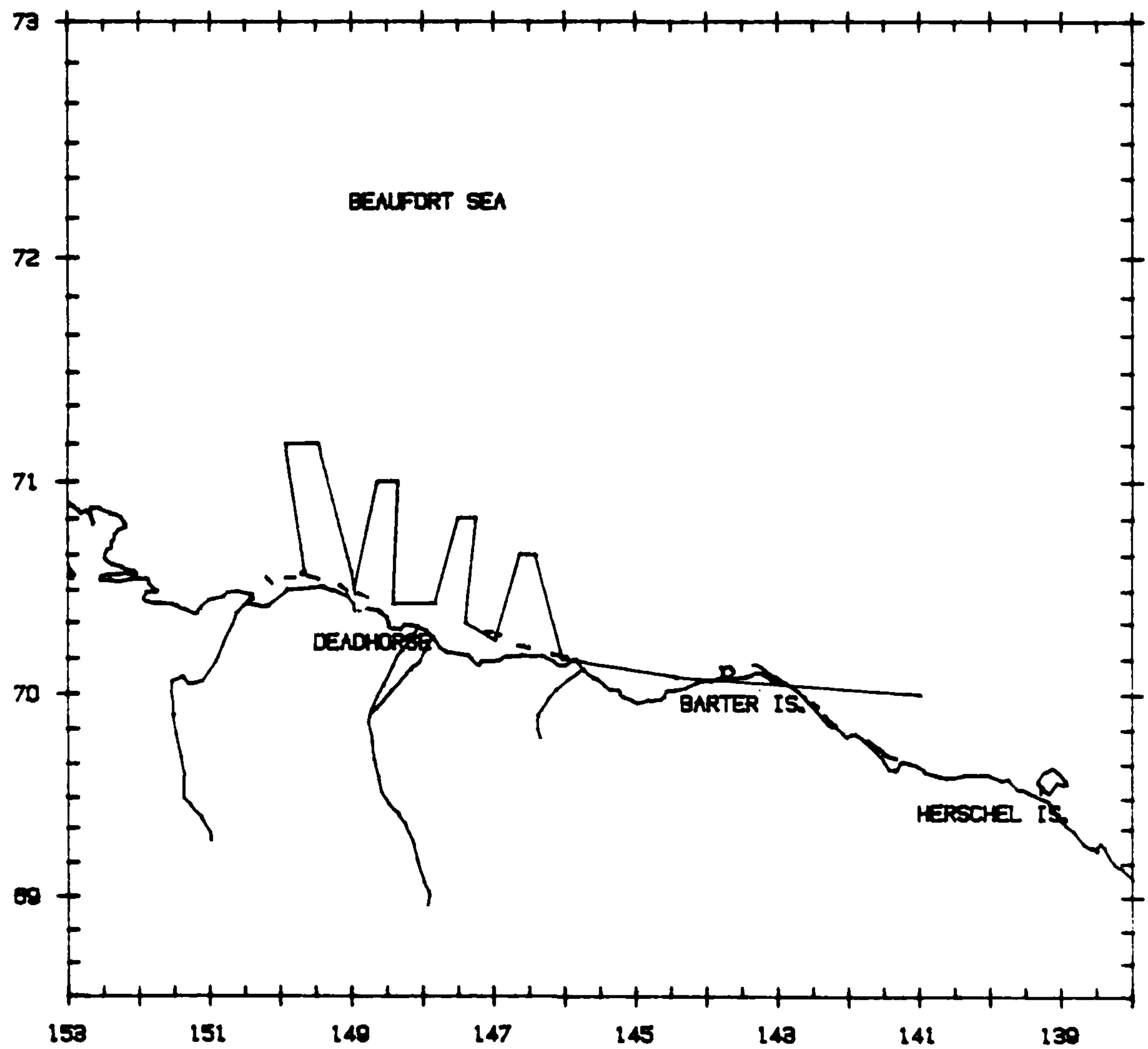
Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°16.9'	142°33.9'	-	SP	MI	-	0	B2	46
1/0	69°44.3'	140°20.5'	-	SP	DI	-	0	B2	24
1/0	70°02.1'	140°52.9'	1548	SP	DI	-	0	B2	49
1/0	69°57.4'	140°55.2'	587	SP	DI	110	0	B2	37
1/0	70°08.6'	141°19.0'	371	BO	SW	60	0	B2	49
1/0	70°14.1'	141°18.7'	-	BO	SW	120	0	B2	40
2/0	70°09.1'	142°07.4'	1650	SP	SW	210	0	B2	26


73
72
71
70
69
150
148
146
144
142
140
138
136
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
RS
PN

302 EH
Flight 3: 12 September 1986

Flight was a transect survey of block 1. Weather was overcast, with high winds in the western half of the block. Visibility was unlimited. Ice cover was 0 to 20 percent. Sea state ranged from Beaufort 03 to 06. No marine mammals were seen.


BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
73
72
71
70
69
153
151
149
147
145
143
141
139

N780
Flight 24: 13 September 1986

Flight was a transect survey of block 15 and the easternmost line in block 16. Weather was overcast with some patchy fog and visibility was variable from 5 km to unlimited. Sea state was Beaufort 03 to 05 and there was no ice. Seven gray whales were seen: one group of four were feeding nearshore and three singles were swimming. Walrus, unidentified pinnipeds, dead walrus, and a dead belukha were also seen.

Gray Whales

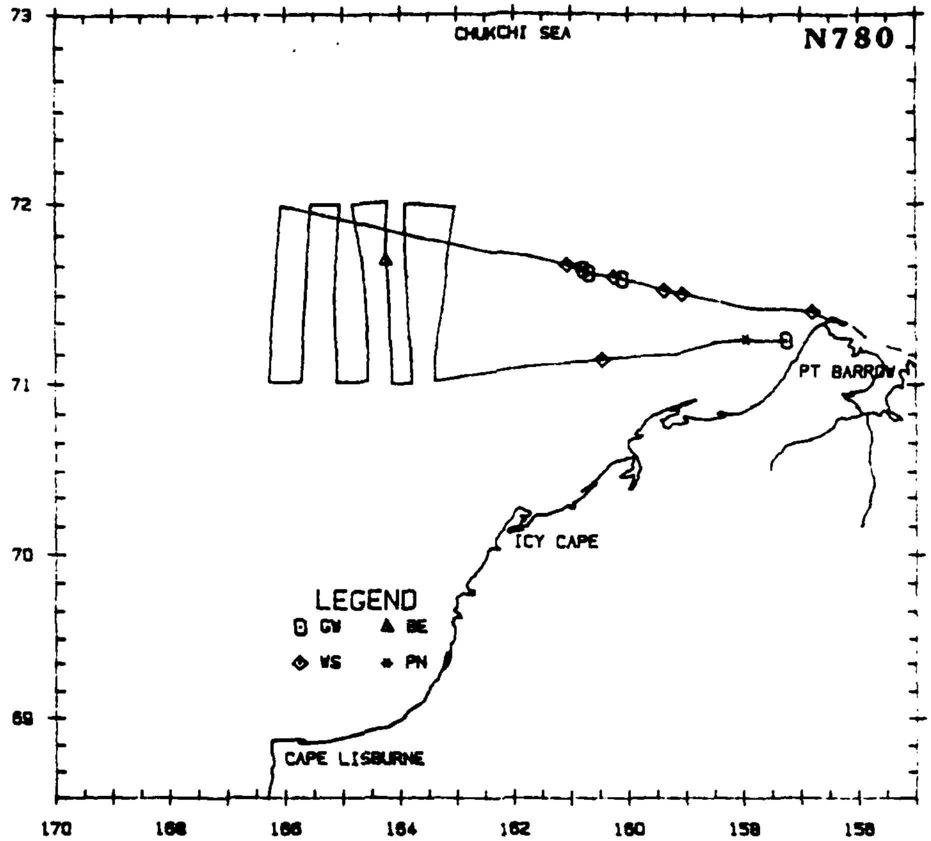
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
4/0	71°14.4'	157°15.0'	-	MP	FE	-	0	B2	18
1/0	71°38.9'	160°47.2'	369	BO	SW	60	0	B2	49
1/0	71°37.5	160°41.0'	981	BO	SW	320	0	B2	49
1/0	71°35.7'	160°06.0'	-	SP	SW	180	0	B2	51

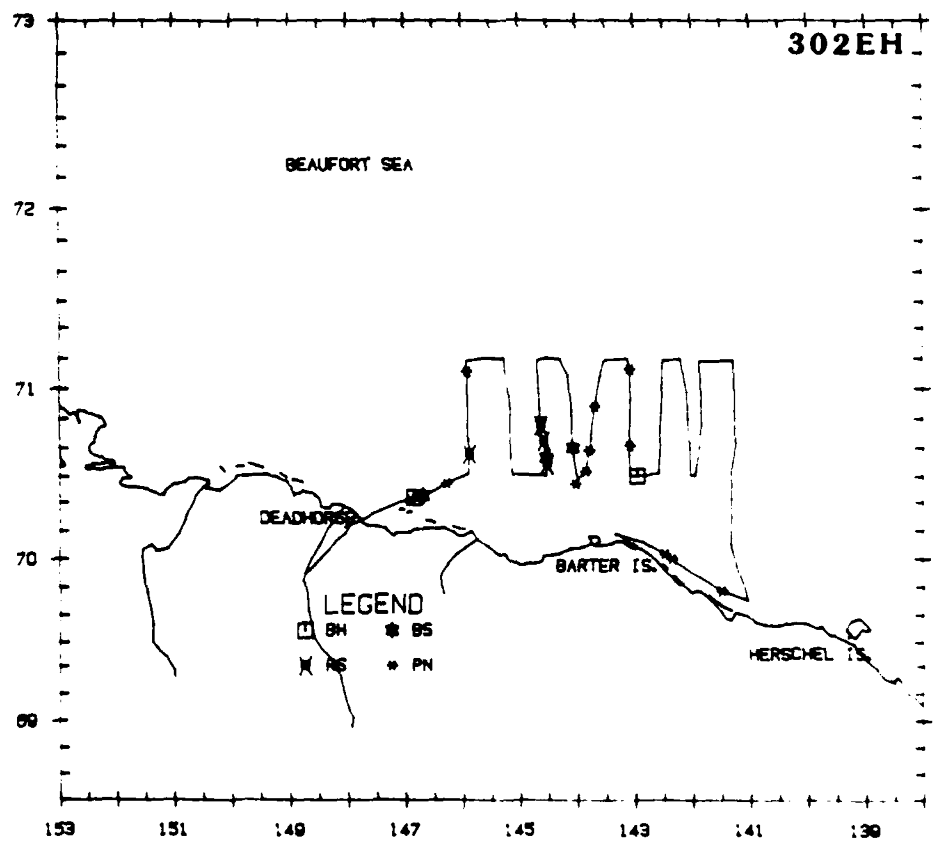
302 EH
Flight 4: 13 September 1986

Flight was a transect survey of block 6 and the western two-thirds of block 7. Weather was clear nearshore with low overcast offshore. Visibility varied from 5 km to unlimited. Ice cover ranged from 0 to 50 percent, with localized areas of 80-percent broken floe cover. Sea state was Beaufort 00 to 04. Two bowheads, bearded seals, ringed seals, and unidentified pinnipeds were seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°21.5'	146°51.3'	654	BO	SW	60	10	B1	11
1/0	70°30.1'	142°57.4'	528	BO	SW	140	0	B2	51


N780
CHUKCHI SEA
PT BARROW
ICY CAPE
CAPE LISBURNE
LEGEND
GW
BE
WS
PN
73
72
71
70
69
170
168
166
164
162
160
158
156

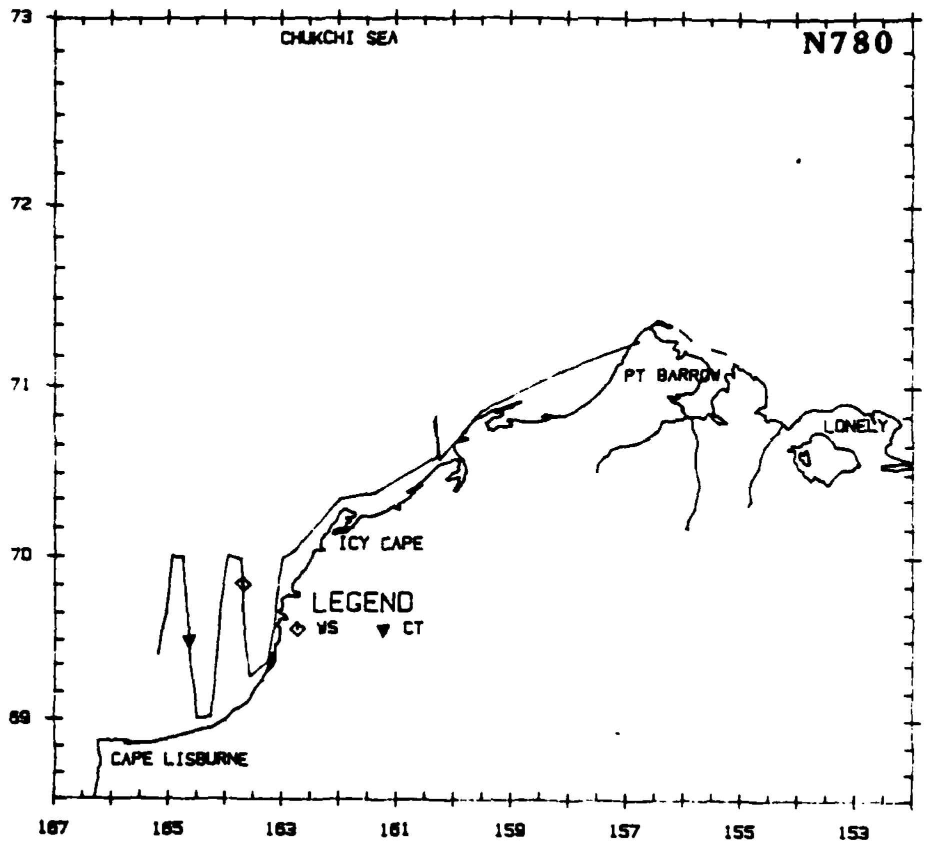

302EH
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BS
RS
PN
73
72
71
70
69
153
151
149
147
145
143
141
139

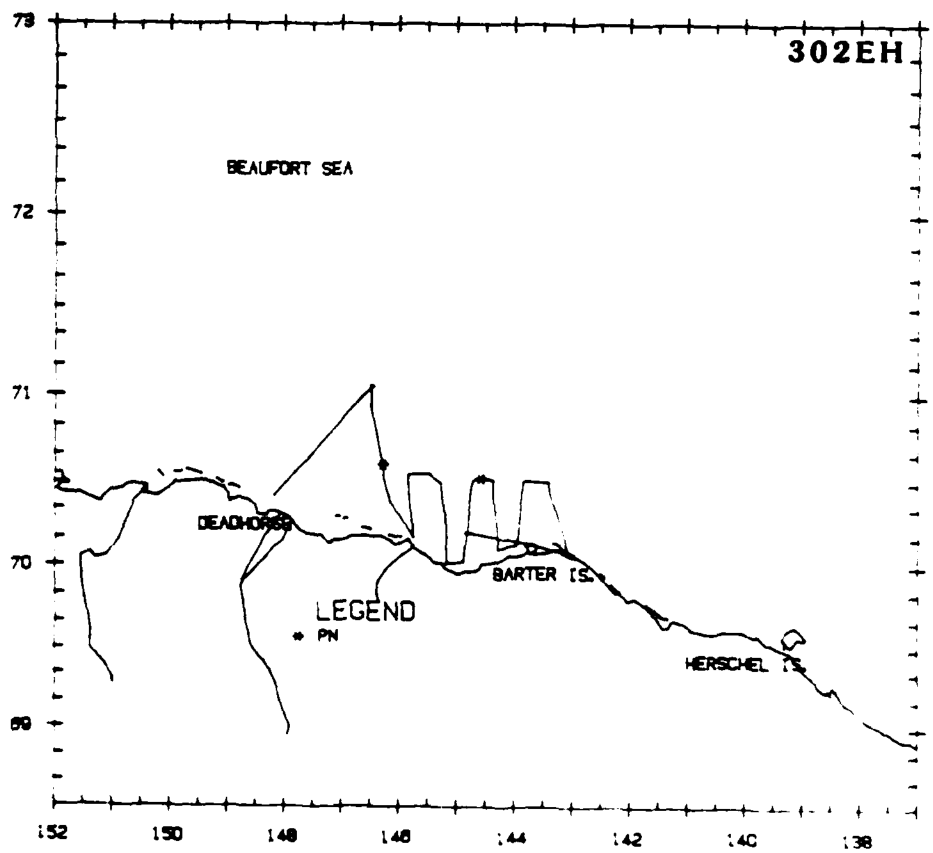
N780
Flight 25: 14 September 1986

Flight was a coastal search survey and a transect survey of the eastern two-thirds of block 20 after high sea states (Beaufort 05 to 06) forced a transect survey of block 17 to be aborted. Failure of the GNS forced the block 20 transect survey to be aborted. Weather was partly foggy with low ceilings and precipitation. Visibility was 2 to 5 km and sea state was Beaufort 02 to 04. One unidentified cetacean was seen momentarily at 69°30.2'N, 164°39.3'W and was described as dark with a dorsal fin. No positive identification was made as the whale was not resighted. Walruses, including one dead walrus, were also seen.

302 EH
Flight 5: 14 September 1986

Flight was a transect survey of block 4 and the eastern one-eighth of block 2. Weather was clear with unlimited visibility in block 4, and low heavy fog in block 2. Ice cover ranged from 0 to 10 percent and sea state was Beaufort 02 to 04. Unidentified pinnipeds were seen.


N780
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
VS
CT
CAPE LISBURNE
73
72
71
70
69
167
165
163
161
159
157
155
153


302EH
BEAUFORT SEA
DEADHORSE
BARTER IS.
LEGEND
PN
HERSCHEL IS.
73
72
71
70
69
152
150
148
146
144
142
140
138

N780
Flight 26: 15 September 1986

Flight was a transect survey of the westernmost line in block 13; the survey and flight were aborted due to GNS failure. Weather was overcast and visibility was unlimited. Sea state was Beaufort 02 and there was no ice. Twenty-eight gray whales were seen feeding and swimming nearshore. Unidentified pinnipeds were also seen.

Gray Whales

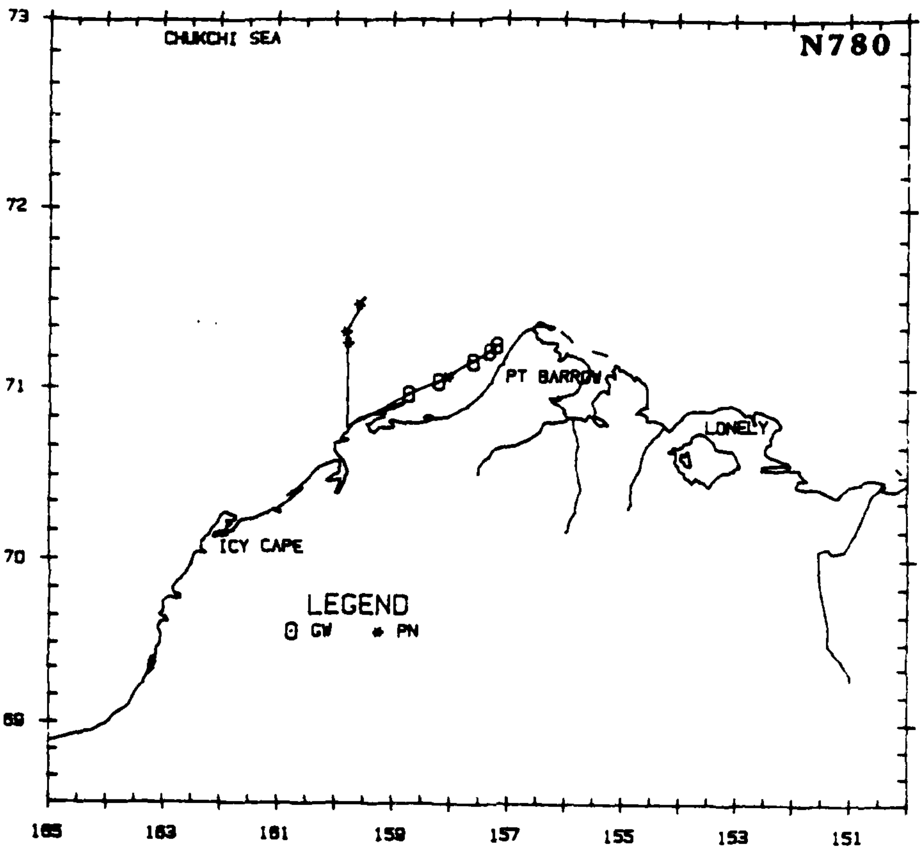
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
5/0	71°14.2'	157°11.4'	-	BW	FE	-	0	B0	18
7/0	71°12.4'	157°18.8'	-	MP	FE	-	0	B0	18
6/0	71°09.0'	157°36.4'	-	BW	FE	-	0	B0	29
6/0	71°02.3'	158°12.4'	-	MP	FE	-	0	B1	20
4/4	70°57.9'	158°43.6'	-	BO	SW	-	0	B1	18

302 EH
Flight 6: 15 September 1986

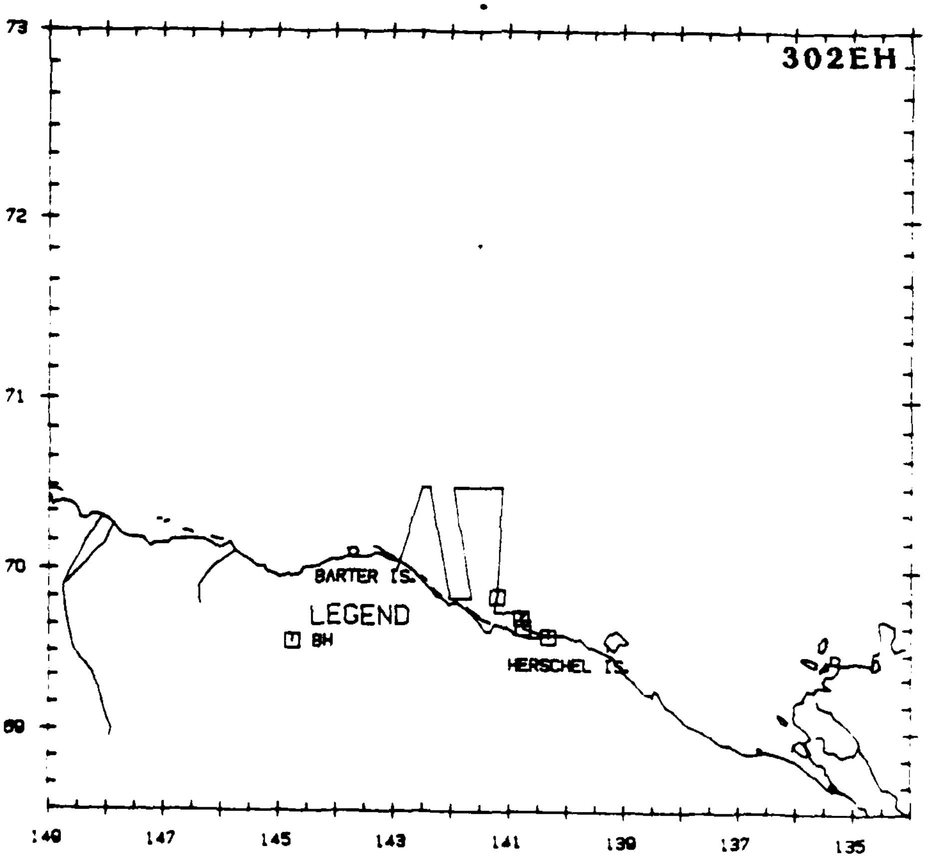
Flight was a transect survey of the western two-thirds of block 5. Weather was partly cloudy with unlimited visibility. Sea state was Beaufort 01 and there was no ice. Eight bowheads were seen within 20 km of shore east of Demarcation Bay.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°50.6'	141°11.6'	565	BO	SW	-	0	B1	24
4/0	69°43.0'	140°47.1'	-	BO	SW	60	0	B1	24
2/0	69°39.5'	140°45.0'	-	BO	SW	150	0	B1	7
1/0	69°36.2'	140°18.5'	-	BO	SW	240	0	B1	16



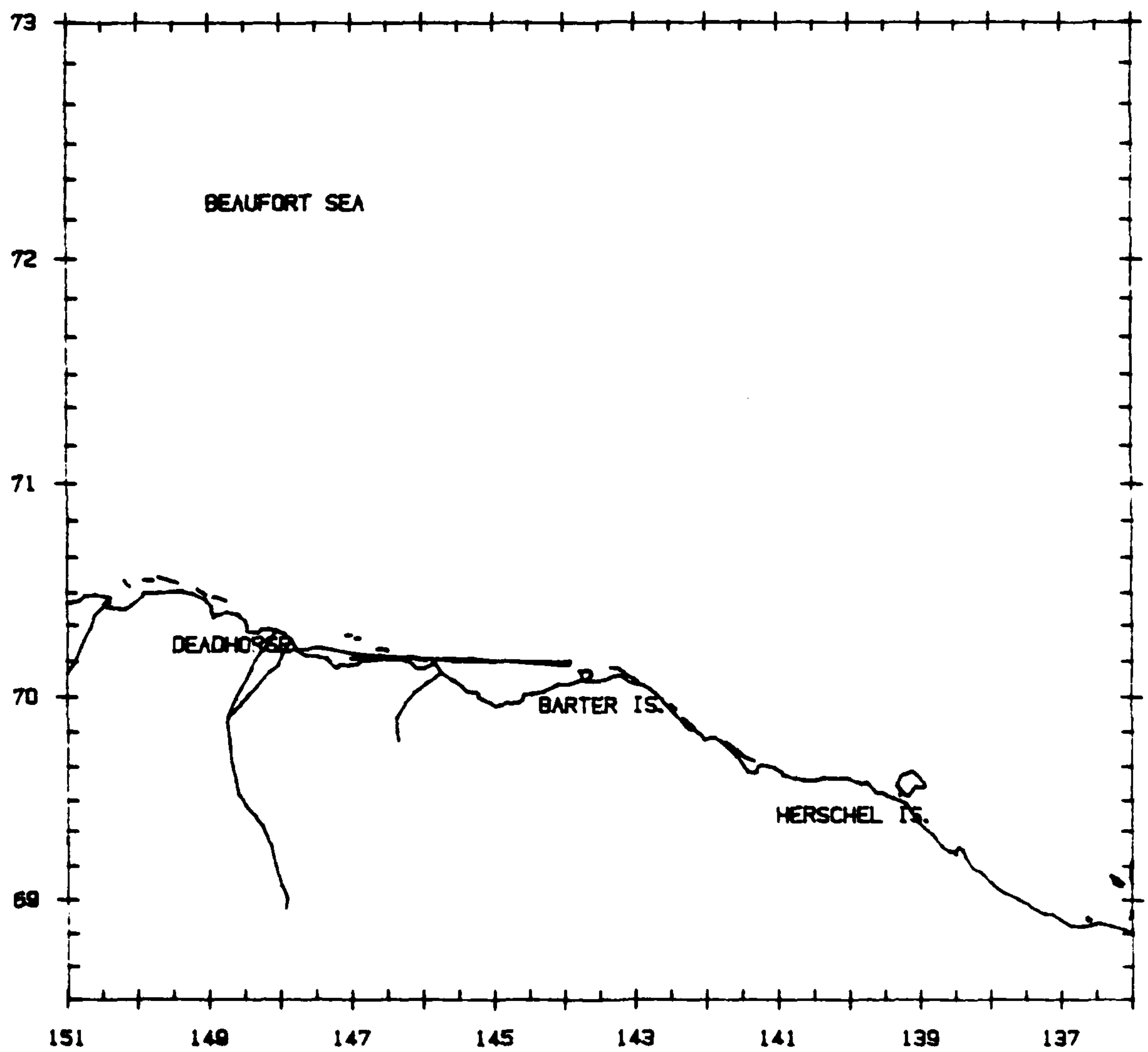
N780
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
GW
PN
73
72
71
70
69
165
163
161
159
157
155
153
151



302EH
BARTER IS.
HERSCHEL IS.
LEGEND
BH
73
72
71
70
69
149
147
145
143
141
139
137
135

N780
Flight 27: 16 September 1986

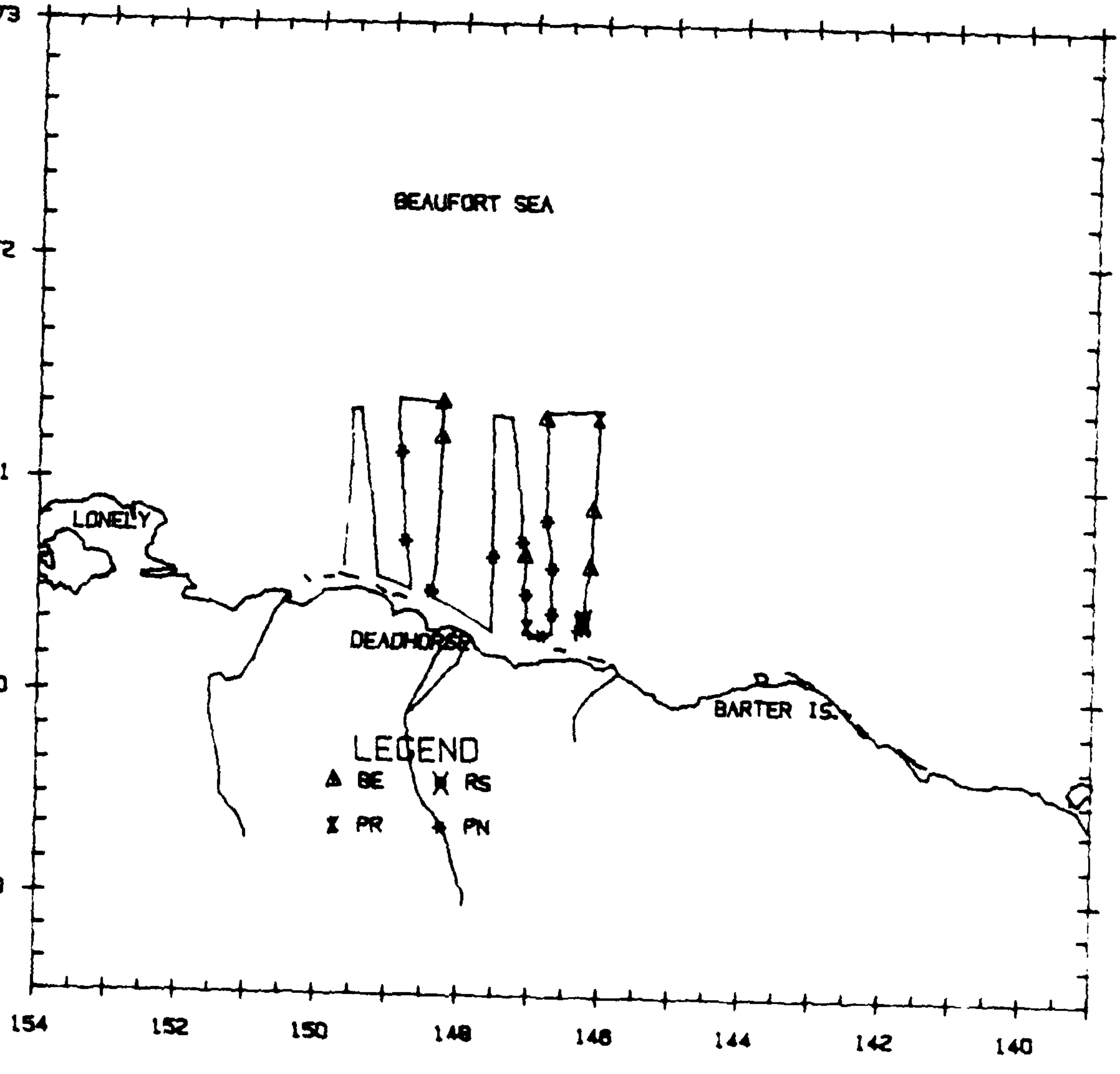
Flight was an attempted survey of block 8 that was aborted due to GNS failure. No marine mammals were seen.



73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
151
149
147
145
143
141
139
137

N780
Flight 28: 17 September 1986

Flight was a transect survey of blocks 1 and 2. The GNS was not functional, so the flight was planned and flown entirely by time and bearing. Weather in the western half of the blocks was partly cloudy with unlimited visibility. However, low-lying fog covered much of the eastern half of the blocks. Ice cover was 0 percent in all but the northernmost areas of block 2, where cover varied from 30- to 80-percent broken floe. Sea state was Beaufort 00 to 01. Belukhas, ringed seals, unidentified pinnipeds, and polar bears were seen.


73
72
71
70
69
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
LEGEND
BE
RS
PR
PN
154
152
150
148
146
144
142
140

N780
Flight 29: 19 September 1986

Flight was a transect survey of the western one-half of block 12 and the eastern five-sixths of block 13. Weather was overcast with unlimited visibility. There was no ice except in the northernmost reaches of block 12 where cover was 65 percent. Sea state was Beaufort 02 to 03. Gray whales were seen in both blocks 12 and 13, and one dead gray whale was seen covered with birds. Walruses, ringed seals, unidentified pinnipeds, and a bearded seal were also seen.

Gray Whales

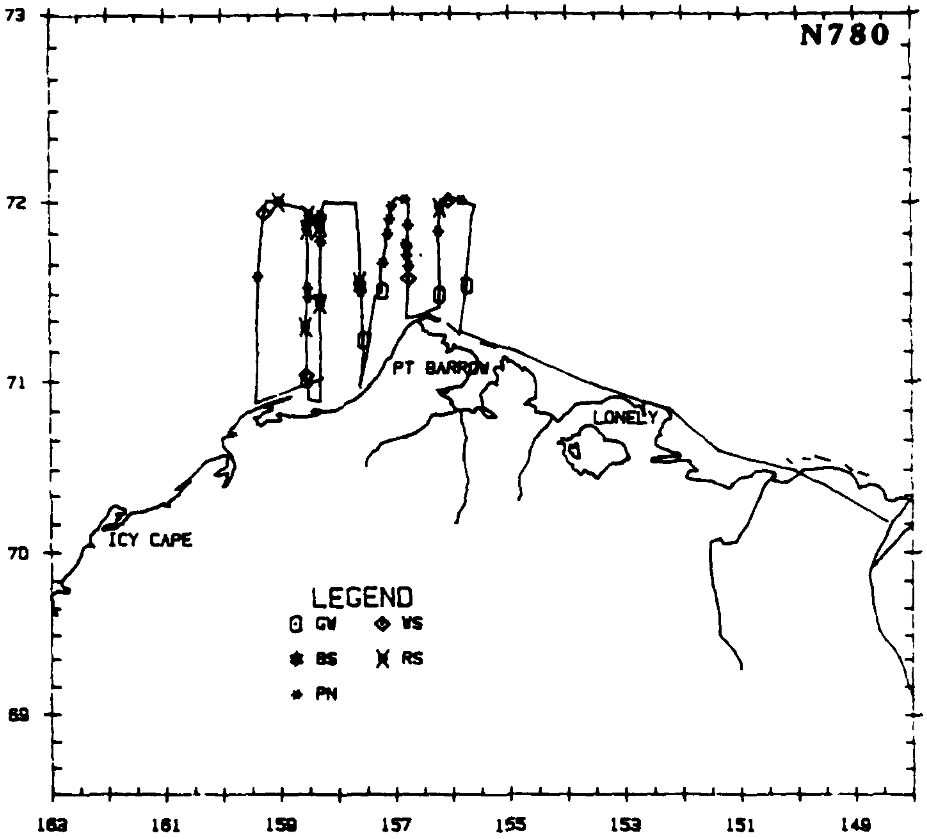
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°32.9'	155°44.5'	-	BO	SW	200	0	B2	18
3/0	71°28.2'	156°13.1'	-	MP	FE	-	0	B2	9
1/0	71°31.0'	157°13.3'	-	BO	DE	-	0	B2	112
2/0	71°13.6'	157°33.3'	371	BO	SW	-	0	B3	38
2/0	71°00.9'	158°33.0'	-	SP	SW	-	0	B3	18

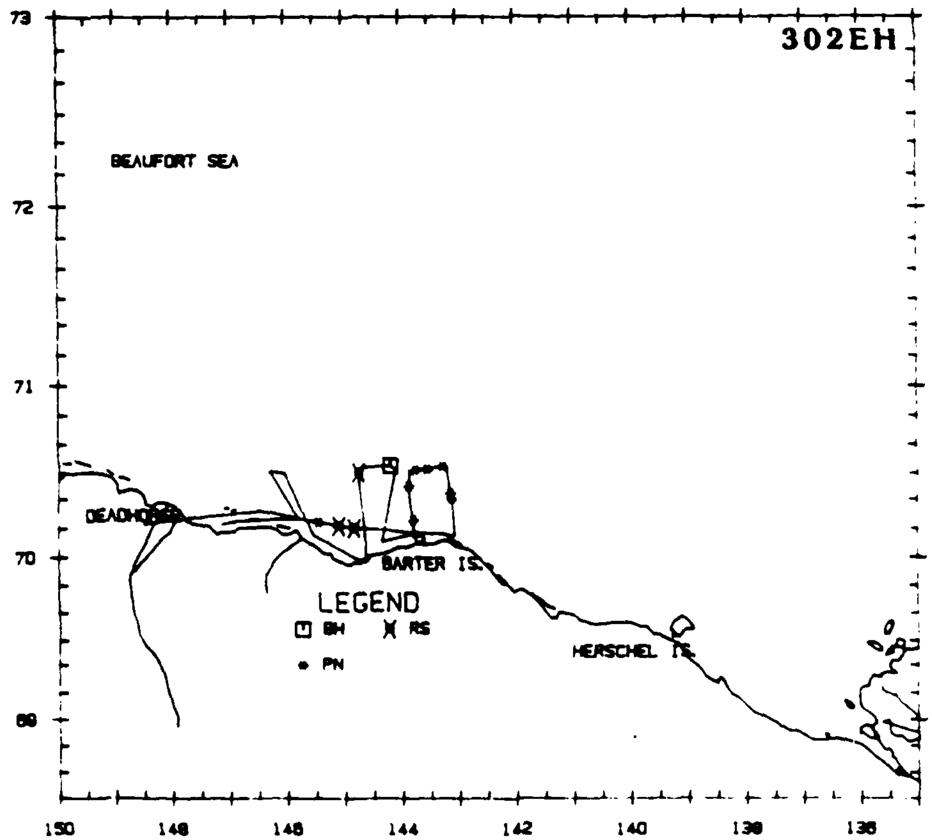
302 EH
Flight 7: 19 September 1986

Flight was a transect survey of block 4. Weather was partly cloudy with unlimited visibility. Ice cover ranged from 0 to 10 percent and sea state was Beaufort 01 to 03. One bowhead was seen approximately 45 km northwest of Barter Island. Ringed seals and unidentified pinnipeds were also seen.

Bowhead Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°32.6'	144°13.0'	792	SP	DI	90	10	B1	49


N780
73
72
71
70
69
163
161
159
157
155
153
151
149
PT BARROW
LONELY
ICY CAPE
LEGEND
GW
WS
BS
RS
PN


302EH
73
72
71
70
69
150
148
146
144
142
140
138
136
BEAUFORT SEA
BARTER IS.
HERSCHEL IS.
LEGEND
BH
RS
PN

N780
Flight 30: 20 September 1986

Flight was a transect survey of the eastern one-half of block 17 and two lines in block 14. Weather was initially overcast with unlimited visibility, but an incoming storm caused rapid deterioration of survey conditions. Sea state ranged from Beaufort 02 to 08. Six live gray whales and one dead gray whale (possibly the same one seen on N780, Flight 29) were seen. Walruses, unidentified pinnipeds, and a bearded seal were also seen.

Gray Whales

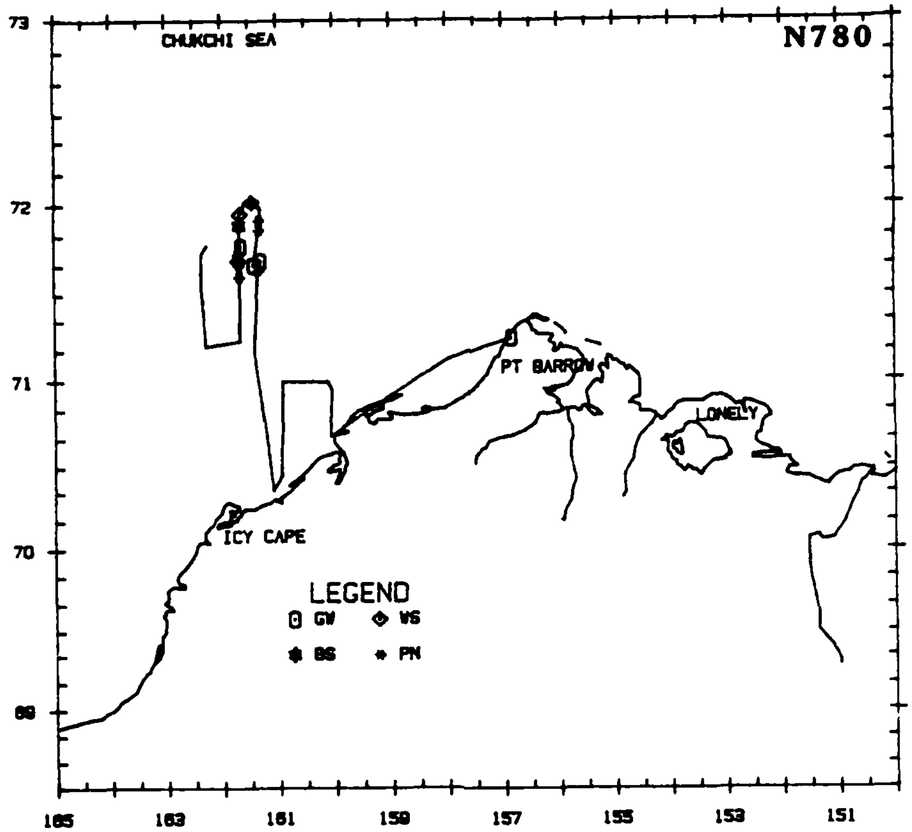
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°14.0'	156°51.2'	585	BW	SW	180	0	B3	5
1/0	71°41.2'	161°17.3'	-	BO	SW	210	0	B3	38
4/0	71°39.9'	161°25.2'	-	BW	FE	-	0	B3	38

302 EH
Flight 8: 20 September 1986

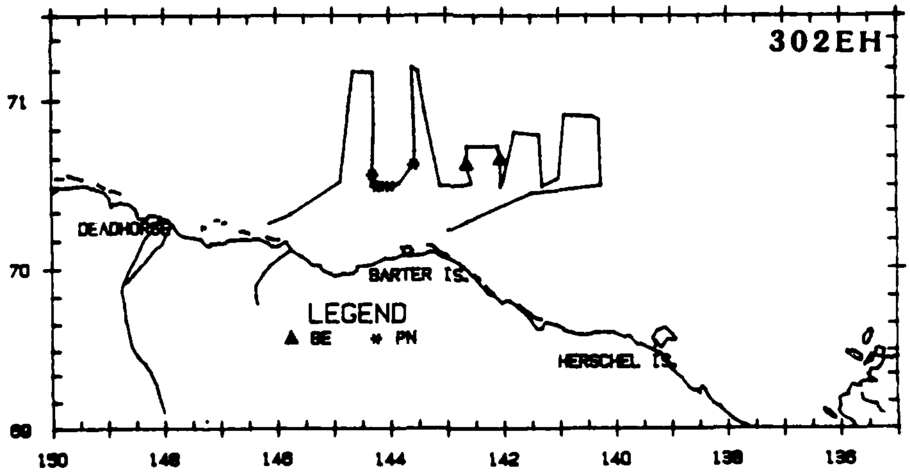
Flight was a transect survey of the southern half of block 7 and two-thirds of block 6. Weather was overcast with fog that caused transect legs in block 7 to be truncated. Visibility was 2 km to unlimited. Ice ranged from 0 to 30 percent and sea state was Beaufort 00 to 02. Belukhas and unidentified pinnipeds were seen.

302 EH
Flight 9: 20 September 1986

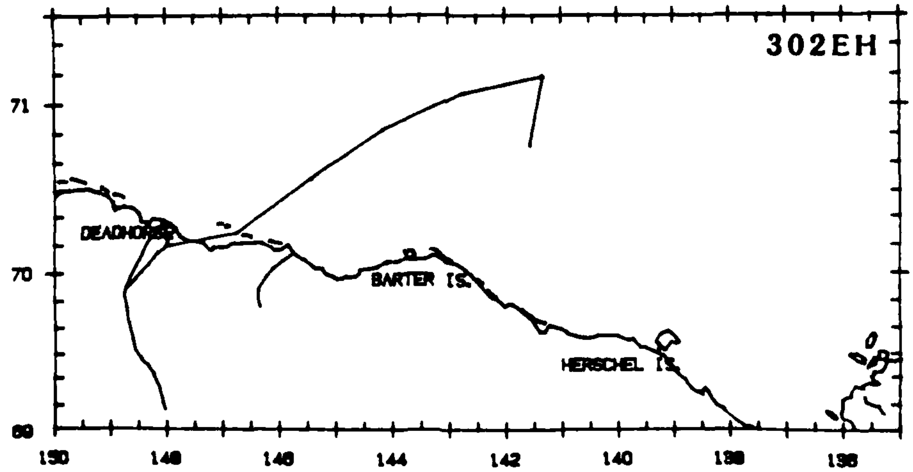
Flight was a search survey survey through blocks 6 and 7 to block 8. Weather was overcast with fog such that conditions were unacceptable for surveying. Ice ranged from 0 to 30 percent and sea state was Beaufort 00 to 02. No marine mammals were seen.



N780
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
GW
WS
BG
PN



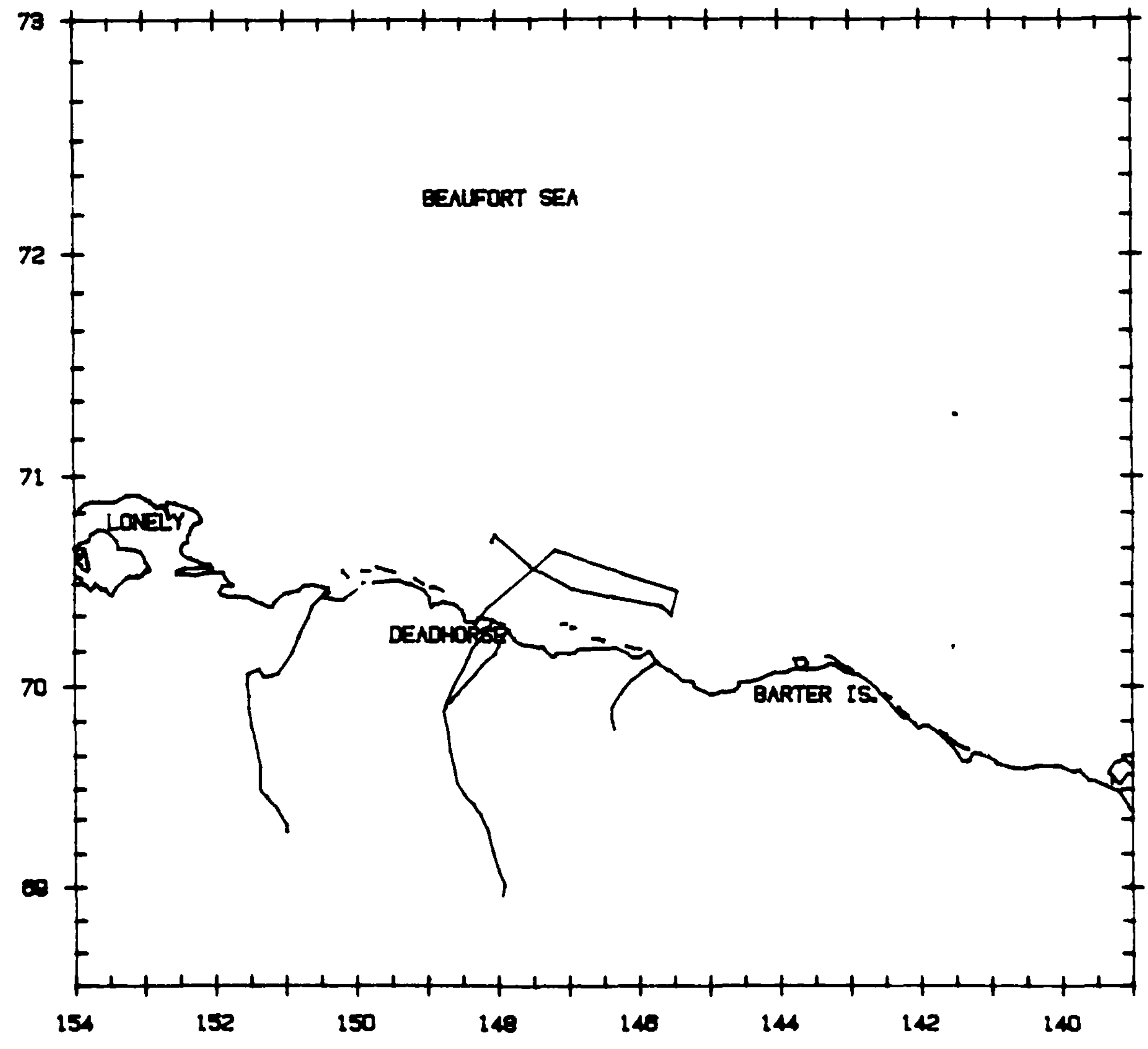
302EH
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BE
PN



302EH
DEADHORSE
BARTER IS.
HERSCHEL IS.

302 EH
Flight 10: 21 September 1986

Flight was planned as a transect survey of block 1 that was aborted due to low-lying fog. A search pattern was flown at 7400 m in an attempt to pick up radio-tagged whales, but none were heard.



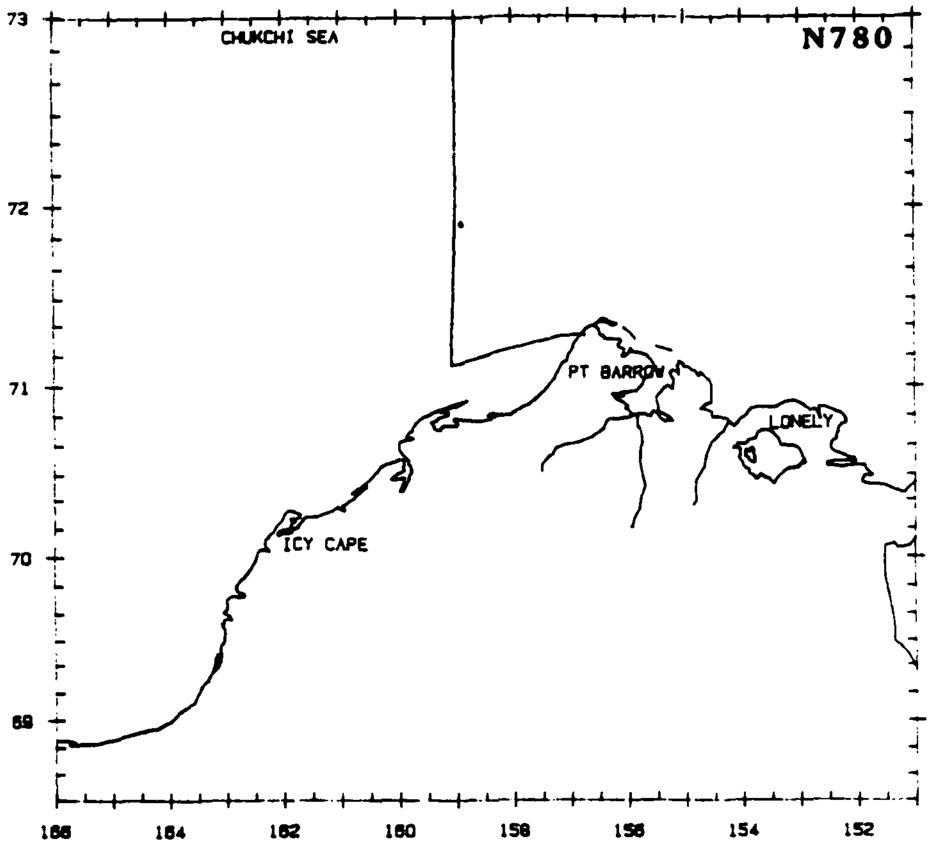
73
72
71
70
69
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
154
152
150
148
146
144
142
140

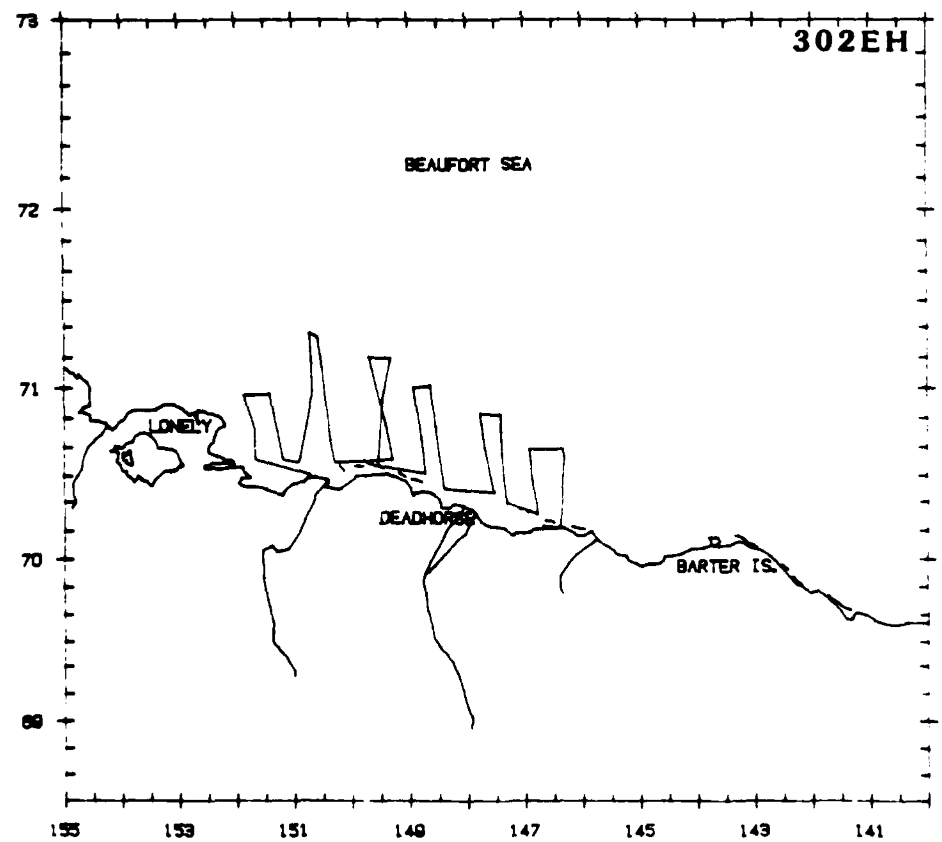
N780
Flight 31: 22 September 1986

Flight was a search survey north to 74°N to find the ice edge. Low ceilings (153 m), fog, snow, and high sea states (Beaufort 03 to 07) precluded flying transect surveys. The ice was first encountered at 73°30'N, 159°W (20 to 30 percent) and was 50 to 60 percent at 74°N, 159°W. No marine mammals were seen.

302 EH
Flight 11: 22 September 1986

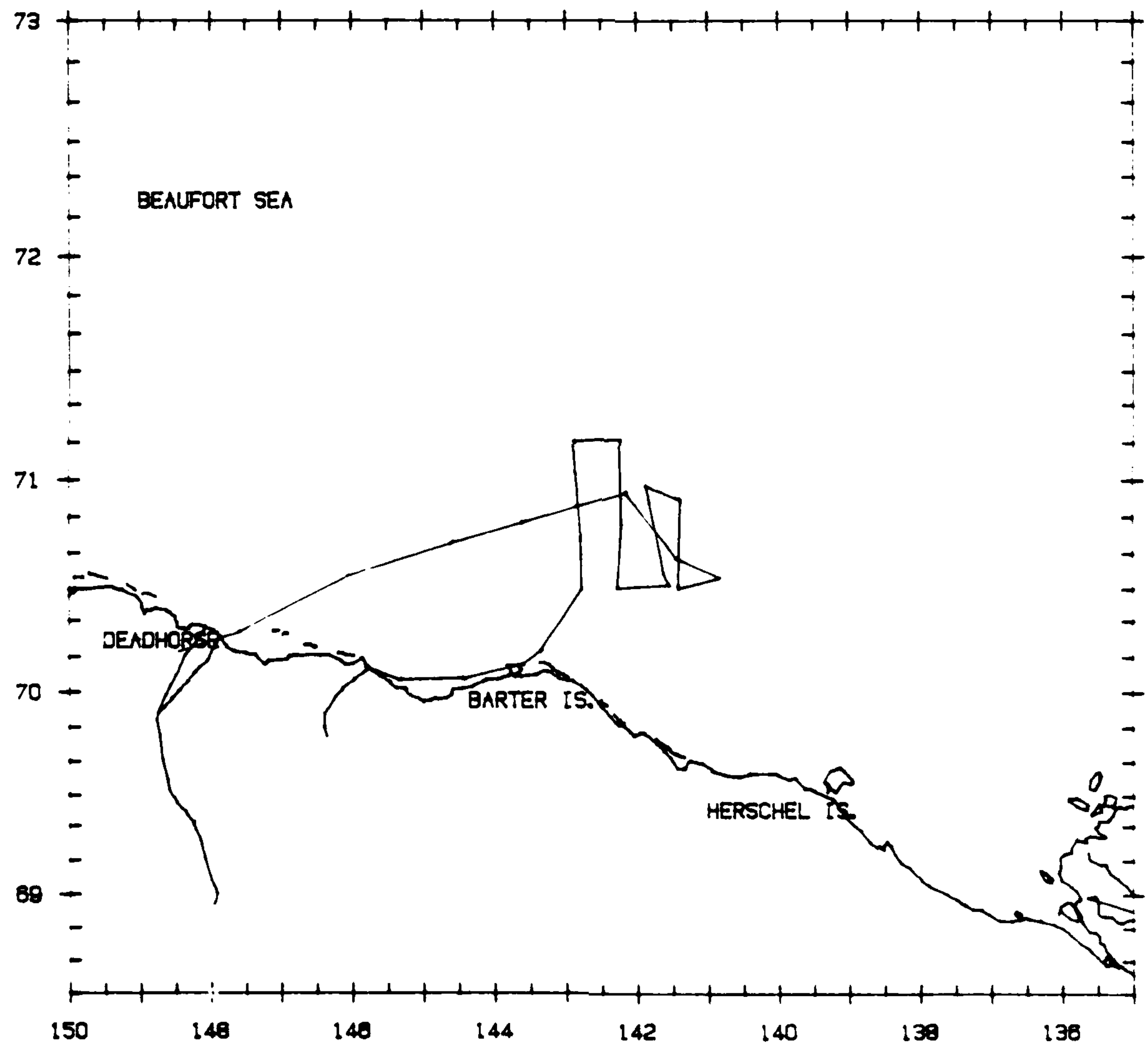
Flight was a transect survey of blocks 1 and the eastern half of 3. Weather was partly cloudy with unlimited visibility. There was no ice in either block and sea state ranged from Beaufort 03 to 06. No marine mammals were seen.


N780
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
73
72
71
70
69
166
164
162
160
158
156
154
152


302EH
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
73
72
71
70
69
155
153
151
149
147
145
143
141

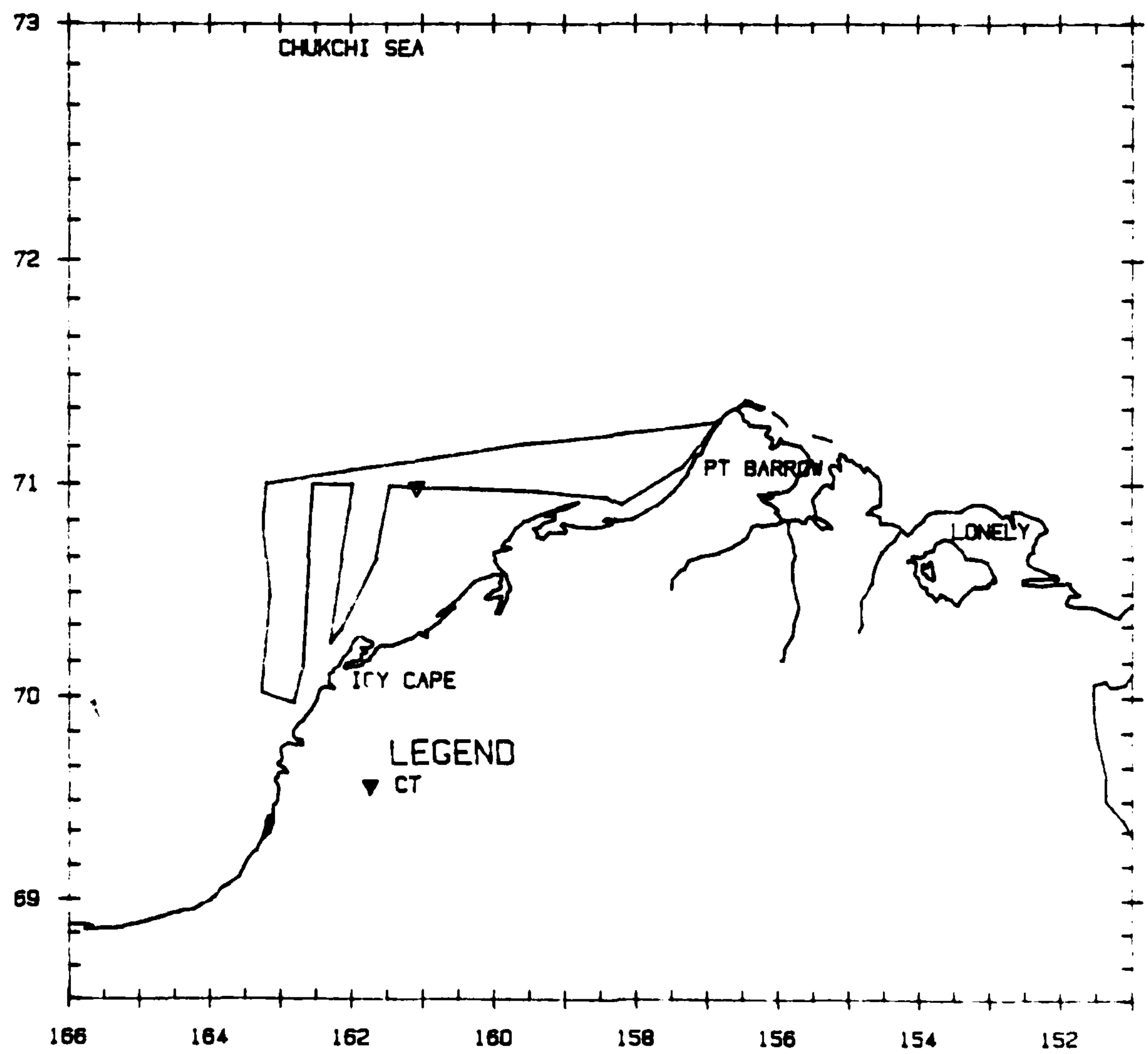
302 EH
Flight 12: 23 September 1986

Flight was a transect survey of the western one-half of block 7. Weather was overcast with snow squalls and visibility varied from 1 km to unlimited. Ice cover ranged from 0 to 20 percent. Sea state varied from Beaufort 03 to 06. No marine mammals were seen.


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
150
148
146
144
142
140
138
136

N780
Flight 32: 24 September 1986

Flight was a transect survey of the western one-half of block 17 and the easternmost leg in block 18. Weather was overcast with some snow squalls. Visibility varied from unlimited to unacceptable. Sea state was Beaufort 03 to 05. Two unidentified cetaceans were seen briefly and could not be positively reidentified. No other marine mammals were seen.


73
72
71
70
69
CHUKCHI SEA
PT BARROW
LONELY
LEGEND
CT
166
164
162
160
158
156
154
152

N780
Flight 33: 25 September 1986

Flight was a transect survey of block 14. Weather was overcast and visibility was unlimited, but sea state was Beaufort 04 to 06. The survey was terminated after completing only the two easternmost legs. Seven gray whales were seen feeding. A walrus was also seen.

Gray Whales

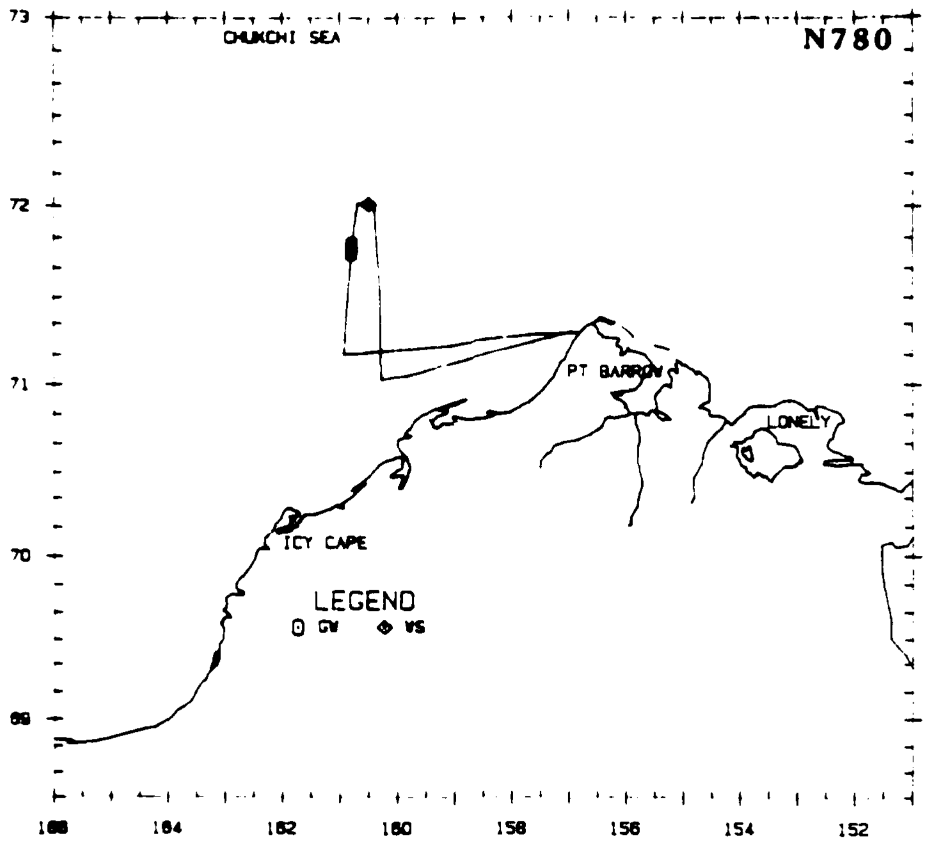
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	71°47.2'	160°48.3'	803	MP	FE	30	0	B5	37
5/0	71°44.9'	160°48.7'	410	MP	FE	-	0	B5	42

302 EH
Flight 13: 25 September 1986

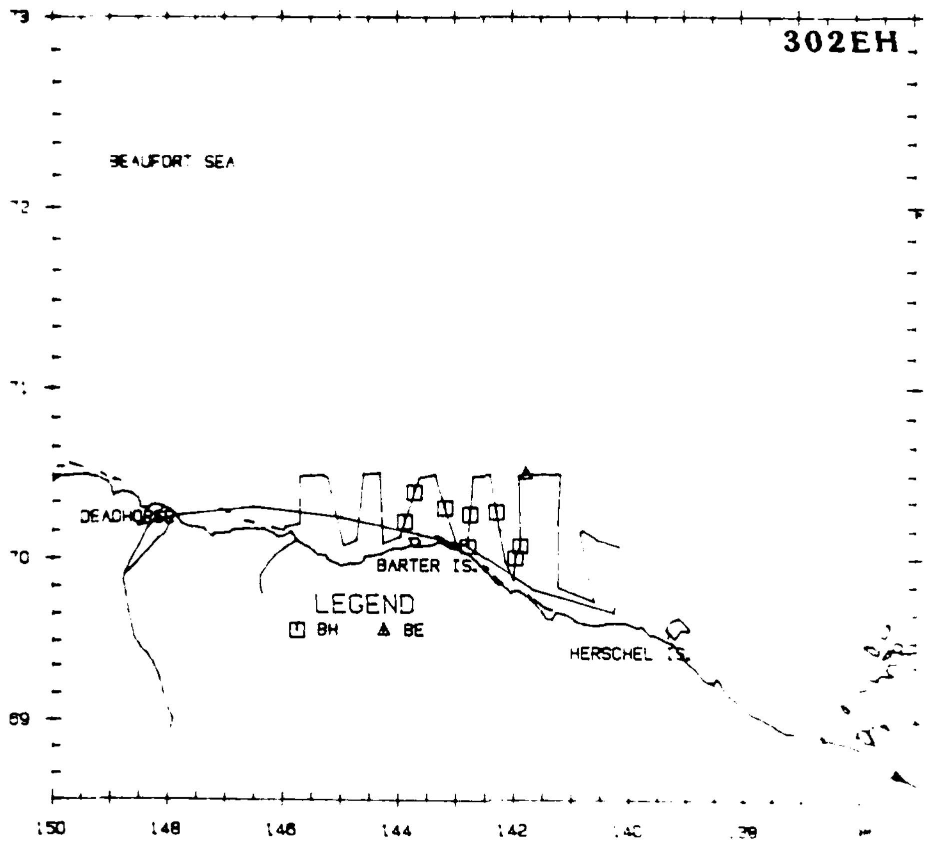
Flight was a transect survey of blocks 4 and 5. Weather was clear with unlimited visibility. Ice cover ranged from 0 to 10 percent in block 5 and there was no ice in block 4. Sea state varied from Beaufort 02 to 03. Nine bowheads were seen, including one calf. Belukhas were also seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°04.7'	142°46.1'	-	BW	UB	-	0	B3	[illegible]
1/0	70°04.6'	141°52.0'	2594	BO	SW	330	0	B3	26
1/0	70°00.3'	141°57.0'	2594	BO	SW	330	0	B3	26
1/0	70°16.6'	142°16.9'	2594	BW	SW	270	0	B3	[illegible]
2/1	70°16.0'	142°44.4'	1407	BW	C/C	270	0	B2	[illegible]
1/0	70°18.2'	143°10.5'	1256	BO	SW	270	0	B2	[illegible]
1/0	70°23.4'	143°42.3'	6540	BW	SW	-	0	B3	40
1/0	70°13.4'	143°52.1'	1256	BO	SW	270	0	B2	15



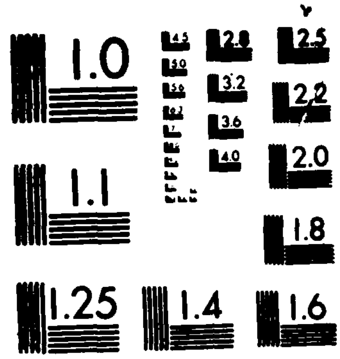
N780
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
GW
VS



302EH
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE

AD-A183 934 DISTRIBUTION ABUNDANCE BEHAVIOR AND BIOACOUSTICS OF ENDANGERED WHALES IN T..(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA D K LJUNGBLAD ET AL. JUL 87 NOSC/TR-1177 4/5

UNCLASSIFIED F/G 8/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

N780
Flight 34: 26 September 1986

Flight was a transect survey of the eastern one-half of block 12 and western five-eighths of block 11. Weather was mostly overcast with some snow squalls and fog. Visibility varied from unlimited to unacceptable. Sea state was Beaufort 01 to 02 and there was no ice except in the northernmost regions where cover was up to 20-percent broken floe. One bowhead was seen swimming west. Belukhas, unidentified pinnipeds, and one dead walrus were also seen.

Bowhead Whale

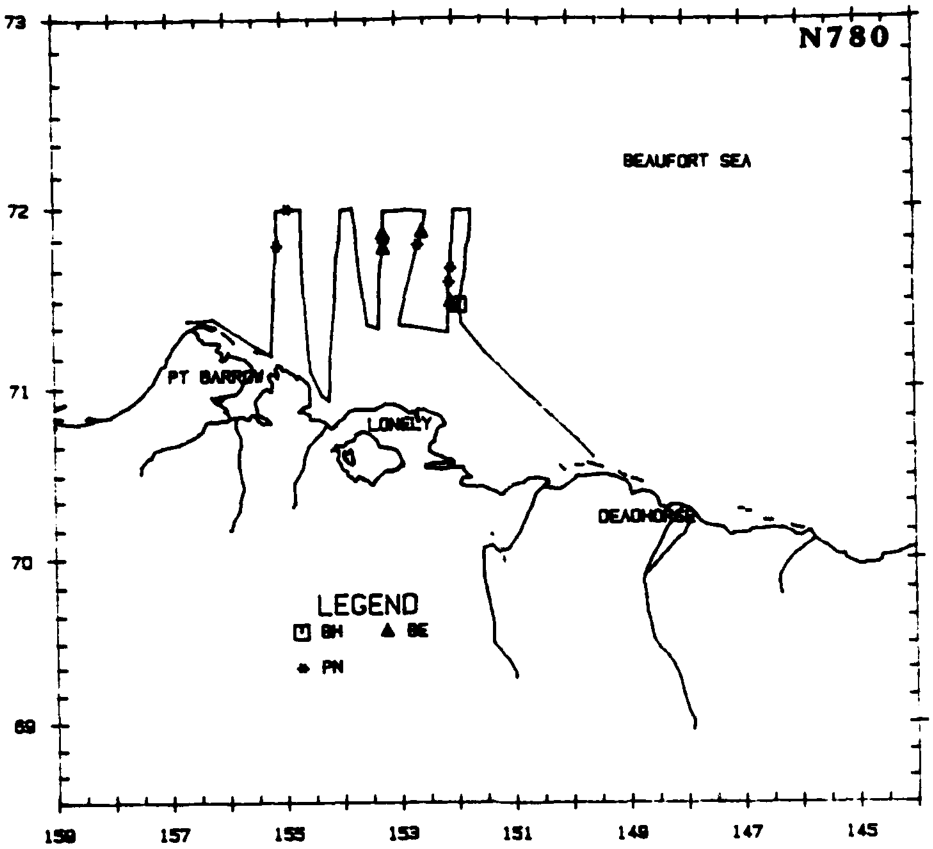
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°27.1'	151°55.8'	1539	SP	SW	240	0	B2	51

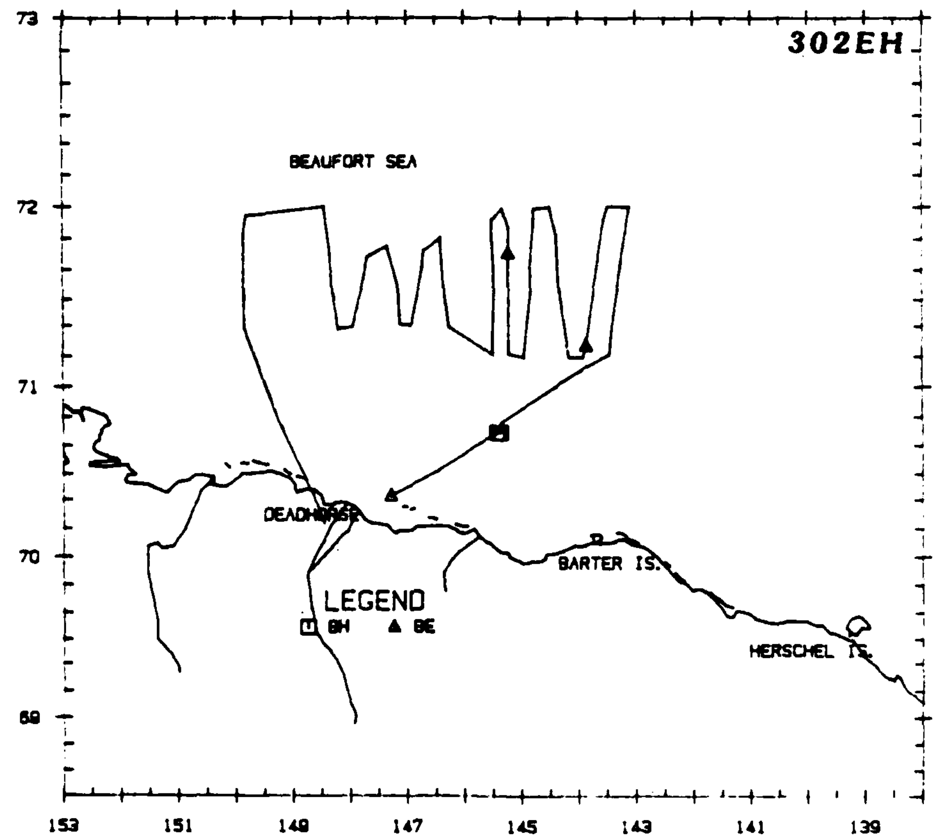
302 EH
Flight 14: 26 September 1986

Flight was a transect survey of block 9 and portions of block 10. Weather was overcast with patches of fog that caused truncation of several transect legs in block 10. Visibility varied from unacceptable to unlimited. Ice cover ranged from 0 to 70 percent in block 9 and there was no ice in block 10. Sea state was Beaufort 00 to 03. Two bowheads were seen enroute to Deadhorse from block 9. Belukhas were also seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°44.5'	145°22.2'	2594	BW	SW	240	0	B3	90
1/0	70°44.4'	145°25.6'	1707	BO	SW	295	0	B3	90


N780
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
LEGEND
BH
BE
PN
73
72
71
70
69
159
157
155
153
151
149
147
145


302EH
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
73
72
71
70
69
153
151
149
147
145
143
141
139

N780
Flight 35: 28 September 1986

Flight was a transect survey of the western one-third of block 14 and all of block 15. Weather was generally overcast with some fog and snow squalls. Visibility varied from 2 km to unlimited. Sea state was Beaufort 03 to 05 and there was no ice. One bowhead was seen offshore swimming west and one gray whale was seen nearshore. Walruses were also seen.

Bowhead Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°45.4'	162°11.9'	610	SP	SW	250	0	B3	33

Gray Whale

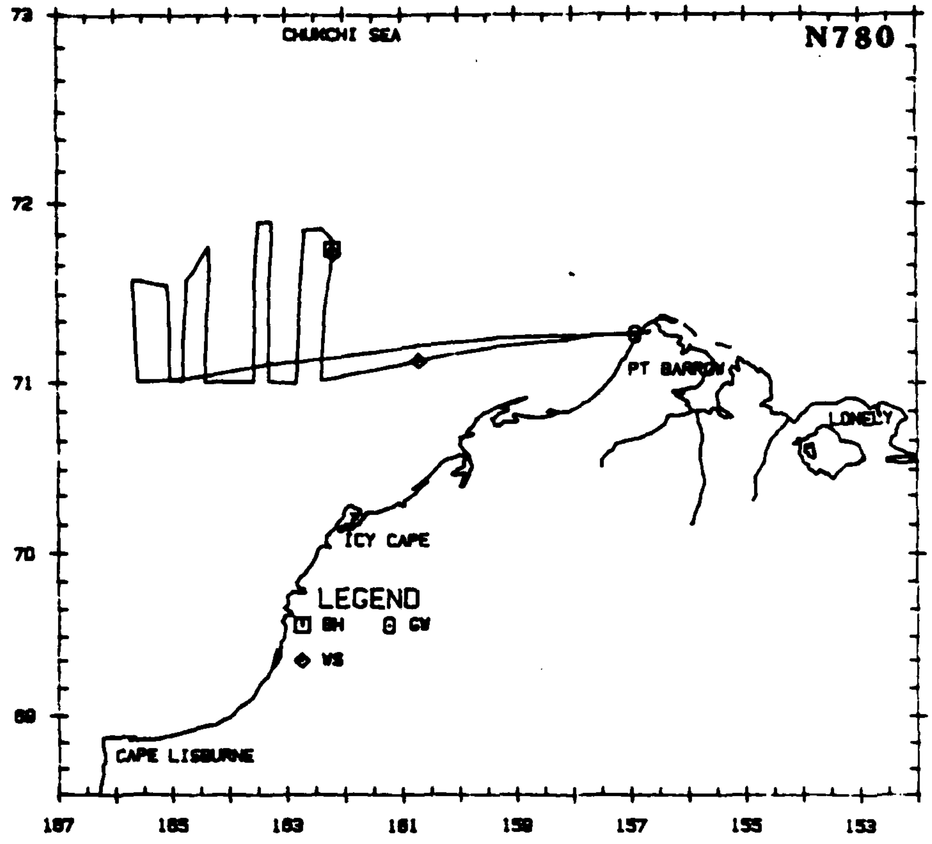
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°16.0'	156°55.0'	-	BO	SW	-	0	B3	18

302 EH
Flight 15: 28 September 1986

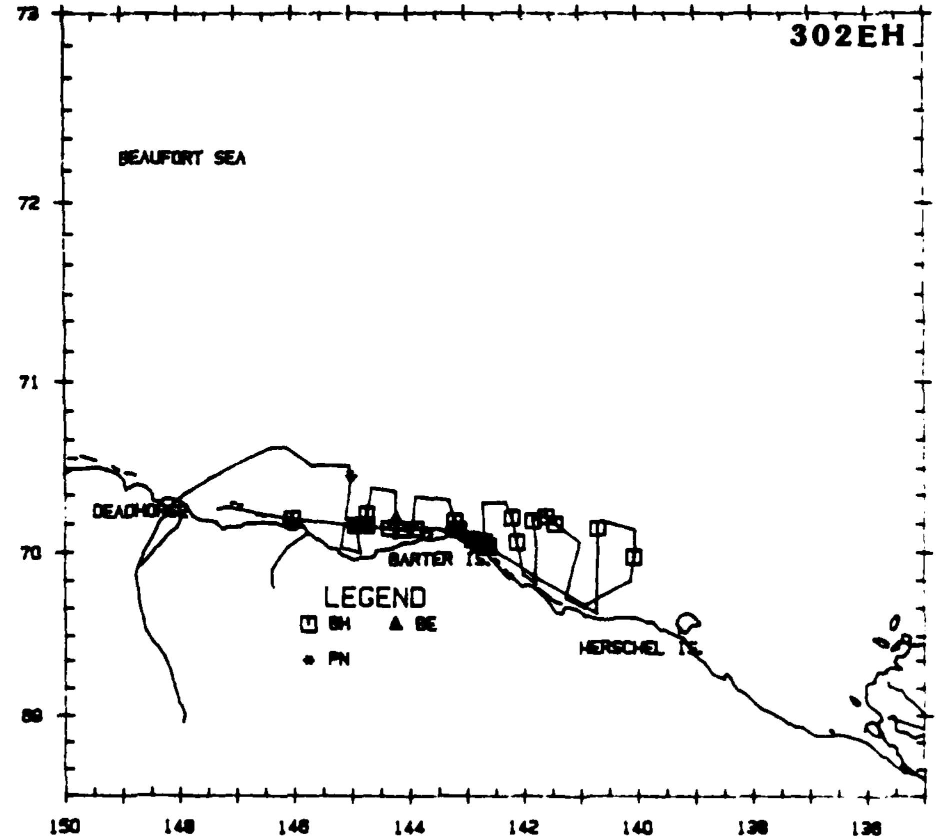
Flight was a transect survey of the southern two-thirds of blocks 4 and 5. Weather ranged from partly cloudy to low overcast. Visibility was mostly unlimited, with localized areas of less than 1 to 3 km. There was no ice and sea state ranged from Beaufort 02 to 03. Twenty-five bowheads were seen, many of them swimming west. Belukhas and unidentified pinnipeds were also seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°09.7'	144°55.4'	235	SP	BR	180	0	B2	15
2/0	70°09.6'	144°44.1'	202	BW	FE	-	0	B2	15
1/0	70°13.5'	144°44.3'	469	BO	SW	220	0	B2	18
1/0	70°11.0'	143°12.6'	226	BO	SW	240	0	B2	18
3/0	70°08.0'	143°08.5'	-	BO	SW	240	0	B2	13
1/0	70°03.0'	142°47.8'	264	BW	SW	270	0	B2	11
1/0	70°03.8'	142°41.3'	264	BW	SW	220	0	B2	11
1/0	70°12.2'	142°12.1'	865	BW	SW	-	0	B2	33
1/0	70°03.5'	142°06.6'	1742	BW	SW	-	0	B3	22
1/0	70°11.2'	141°49.7'	397	BW	RE	90	0	B2	40
1/0	70°12.7'	141°36.1'	865	BW	RE	360	0	B3	53
1/0	70°10.1'	141°26.4'	469	BW	SW	-	0	B3	53
1/0	70°08.5'	140°41.5'	218	BO	SW	270	5	B2	46
1/0	69°58.5'	140°03.7'	218	BO	RE	90	0	B3	49
1/0	70°02.3'	142°36.9'	128	BO	SW	270	0	B2	18
1/0	70°04.7'	142°54.3'	218	BO	SW	270	0	B2	11
1/0	70°08.3	143°53.5'	865	BO	SW	270	0	B2	9
2/0	70°08.3	144°05.1'	865	BO	SW	270	0	B2	11
1/0	70°08.6'	144°20.7'	419	SP	SW	235	0	B2	15
1/0	70°09.6'	144°50.0'	55	SP	SW	-	0	B2	15
1/0	70°11.9'	146°01.6'	1742	BO	SW	-	0	B2	5



N780
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
BH
GV
VS
CAPE LISBURNE



302EH
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
BE
PN

N780
Flight 36: 29 September 1986

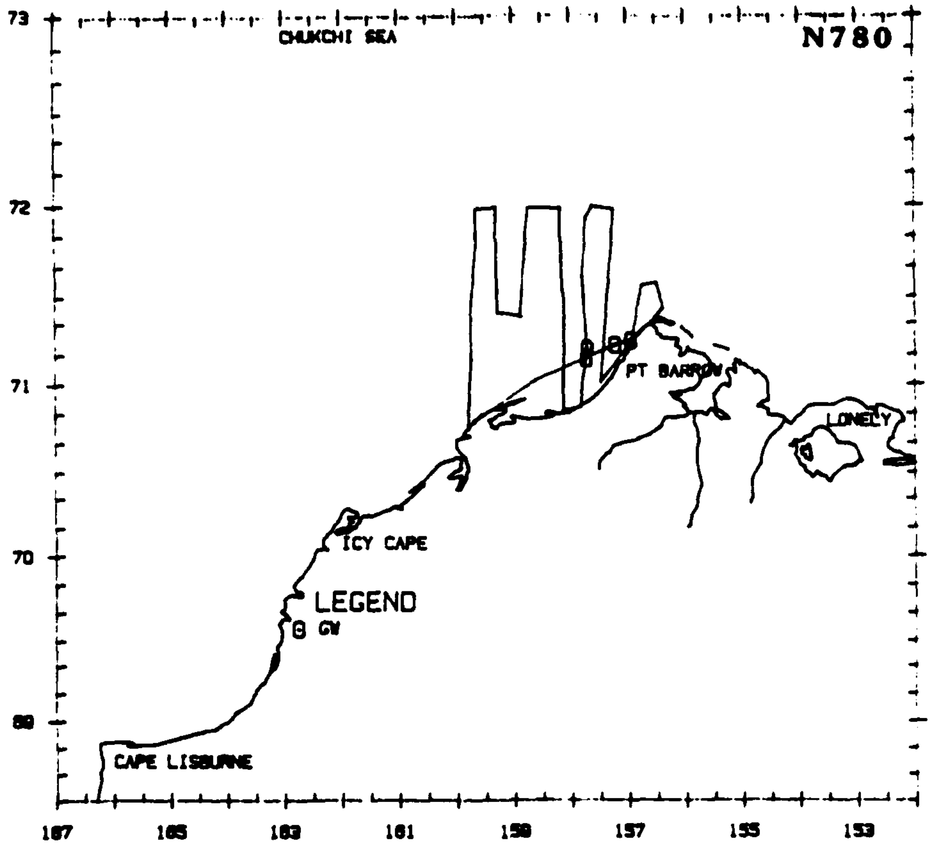
Flight was a transect survey of block 13 and the western one-third of block 12. Some transect legs had to be truncated due to fog, snow squalls or low ceilings, and visibility varied from unlimited to unacceptable. Sea state was Beaufort 02 to 06 and there was no ice. Six gray whales were seen nearshore, mostly feeding.

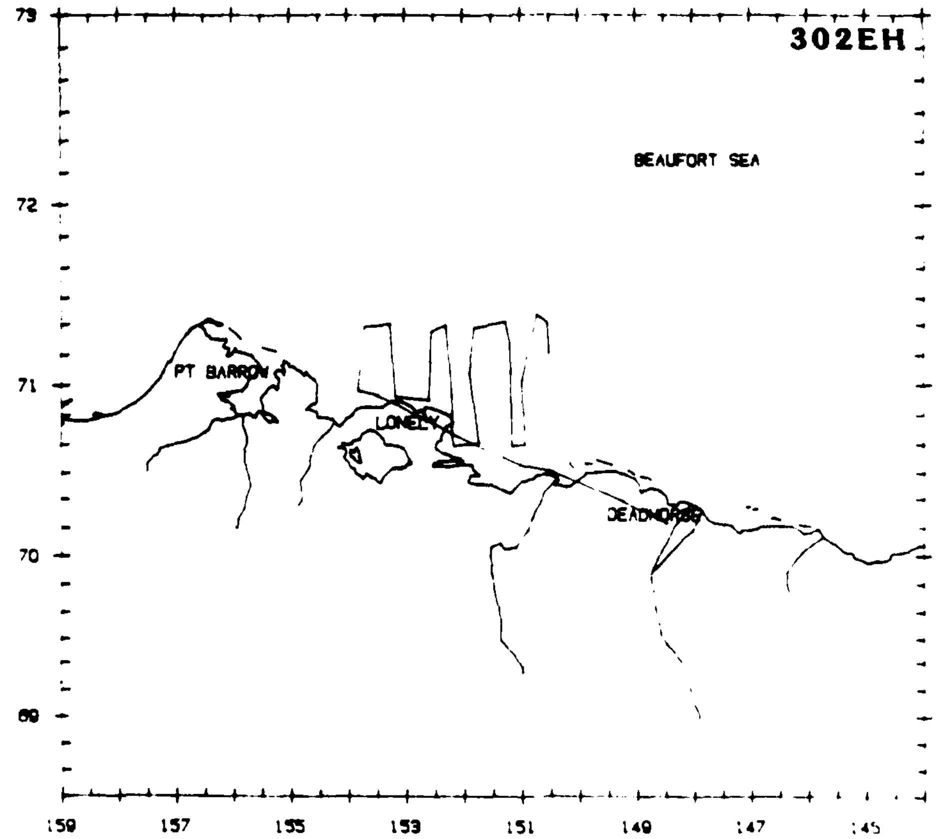
Gray Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°14.7'	156°56.4'	246	BO	SW	330	0	B3	5
1/0	71°13.2'	157°13.1'	-	MP	FE	220	0	B3	18
3/0	71°08.5'	157°43.4'	766	MP	FE	-	0	B3	22
1/0	71°11.9'	157°42.9'	707	MP	FE	-	0	B3	42

302 EH
Flight 16: 29 September 1986

Flight was a transect survey of block 3. Weather was overcast and visibility varied from 5 km to unlimited. There was no ice and sea state ranged from Beaufort 03 to 05. No marine mammals were seen.


N780
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
GV
CAPE LISBURNE
73
72
71
70
69
167
165
163
161
159
157
155
153

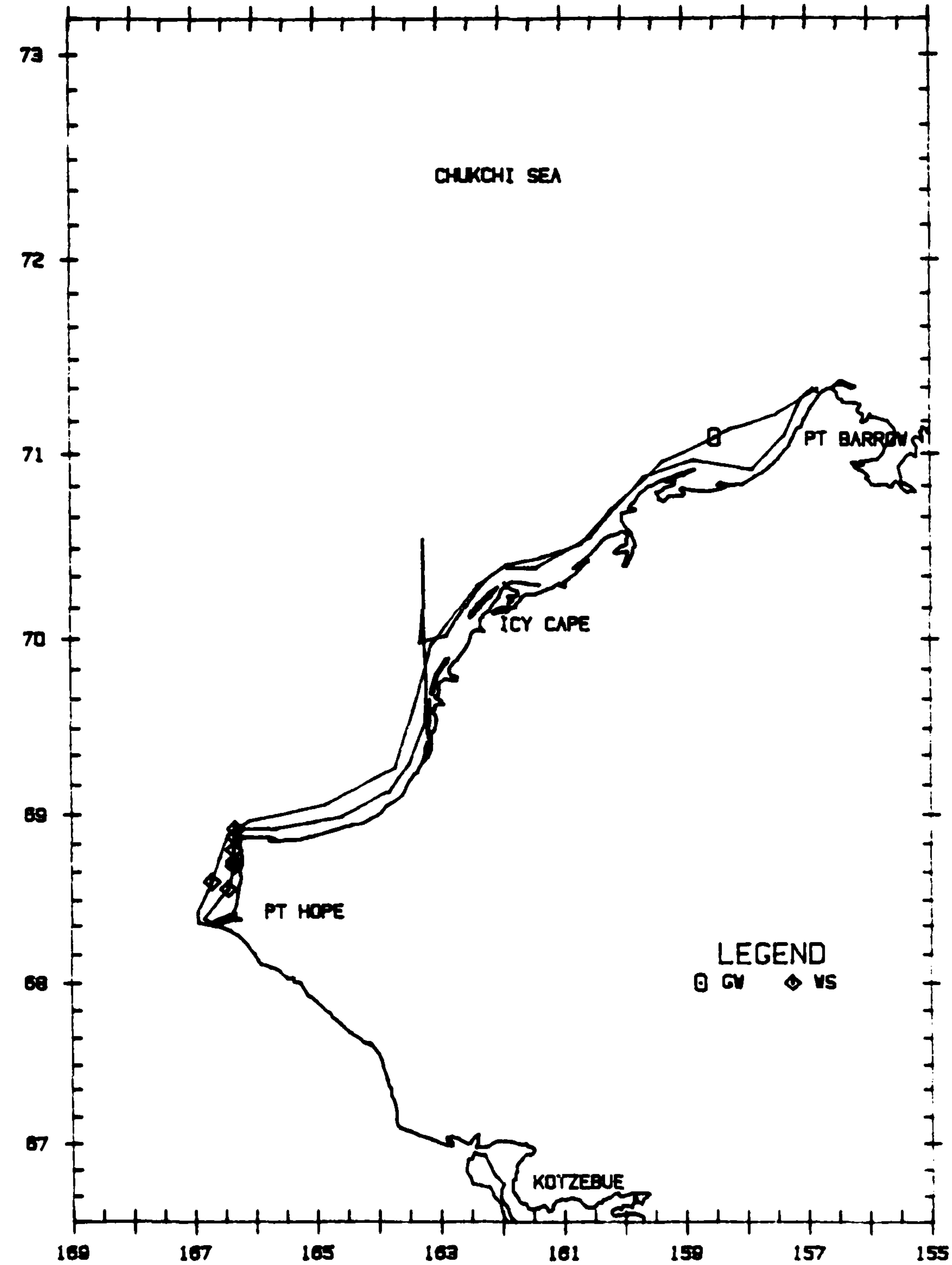

302EH
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
73
72
71
70
69
159
157
155
153
151
149
147
145

N780
Flight 37: 30 September 1986

Flight was coastal search survey to Point Hope after unacceptable high sea states (B05-06) forced an attempted transect survey of block 18 to be aborted. Weather was overcast with low ceilings and visibility was 5 km to unlimited. Sea states along the coastline varied from Beaufort 02 to 04, and there was no ice. One gray whale was seen feeding. Walruses were also seen.

Gray Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°05.0'	158°29.0'	585	MP	FE	140	0	B4	18



CHUKCHI SEA
PT BARROW
ICY CAPE
PT HOPE
KOTZEBUE
LEGEND
GW
WS
73
72
71
70
69
68
67
169
167
165
163
161
159
157
155

N780
Flight 38: 1 October 1986

Flight was a transect survey of the western one-half of block 12, eastern two-thirds of block 17 and southeast two-thirds of block 14. Weather was partly cloudy and visibility was unlimited except for areas with glare. Sea state was Beaufort 02 to 03 and there was no ice. Eleven gray whales were seen, mostly feeding. Belukhas, unidentified pinnipeds, a bearded seal, and a walrus were also seen.

Gray Whales

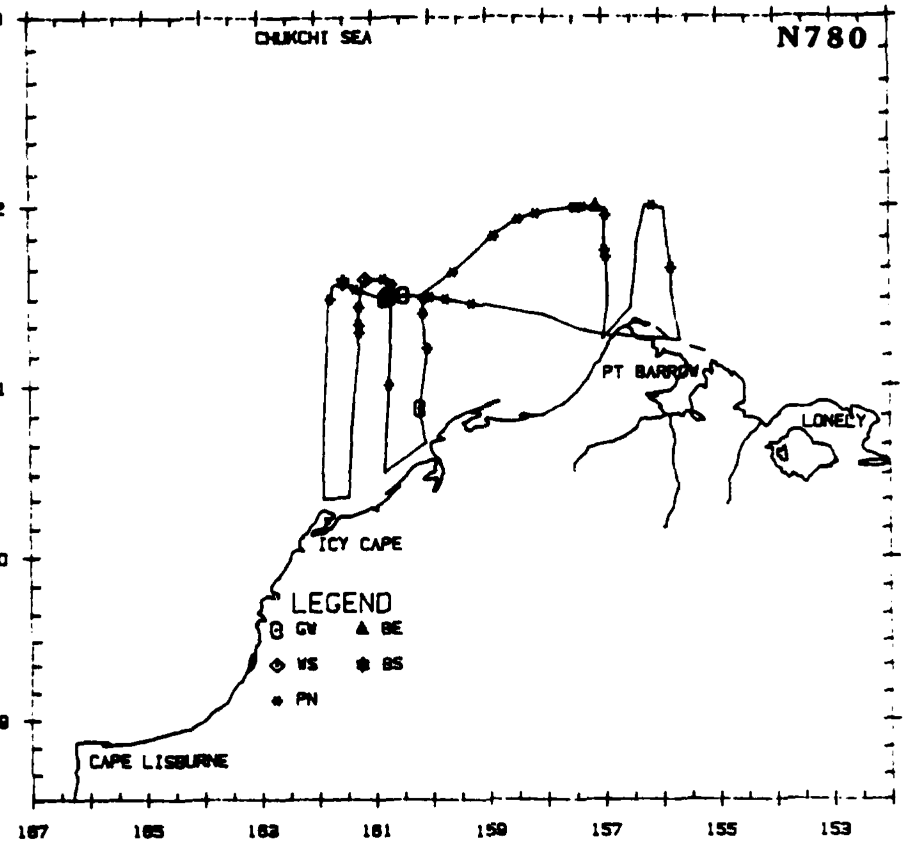
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°52.6'	160°12.2'	-	BW	SW	300	0	B2	33
6/0	71°30.1'	160°48.4'	-	MP	FE	-	0	B2	49
3/0	71°29.7'	160°45.6'	-	BW	FE	-	0	B2	49
1/0	71°29.8'	160°27.7'	-	BO	FE	-	0	B2	42

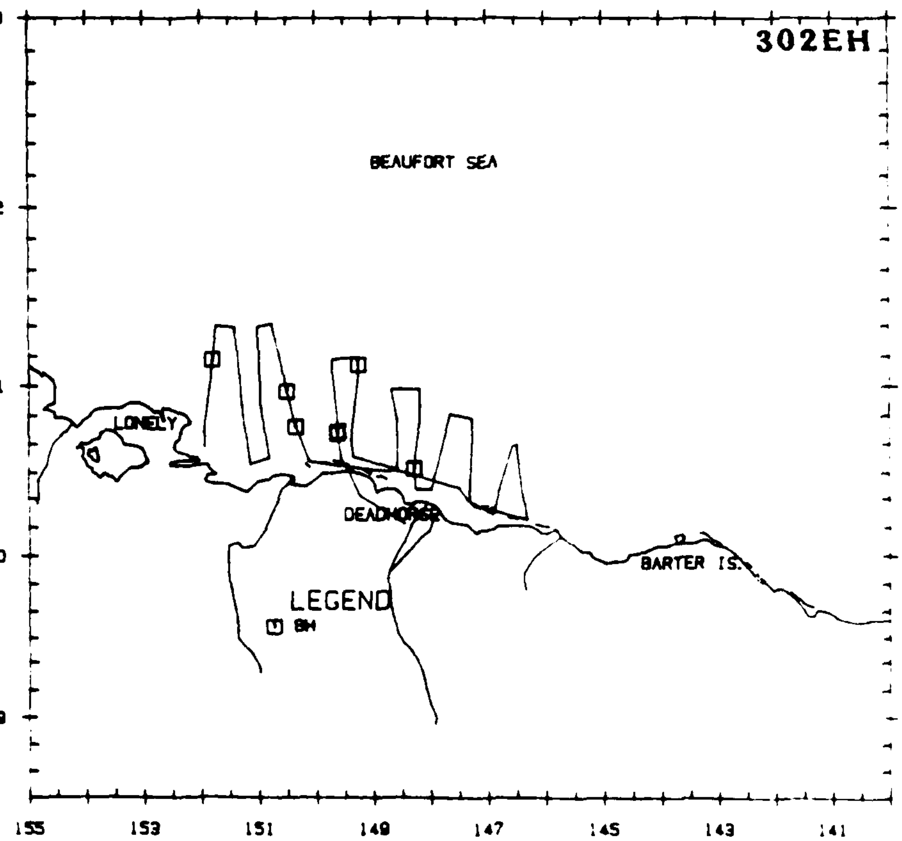
302 EH
Flight 17: 1 October 1986

Flight was a transect survey of block 1 and the eastern two-thirds of block 3. Weather was overcast with patchy fog. Visibility varied from 2 km to unlimited. There was no ice and sea state ranged from Beaufort 02 to 04. Twelve bowheads were seen; one breached 3 times, then rolled and flipper slapped at the surface.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/1	70°43.9'	149°38.4'	528	BO	C/C	345	0	B2	9
1/0	70°44.7'	149°36.9'	885	BO	SW	345	0	B2	9
2/0	71°07.2'	149°15.6'	1729	BW	SW	300	0	B3	40
1/0	70°31.6'	148°16.8'	563	SP	SW	240	0	B3	15
2/0	70°29.9'	148°17.0'	1037	BO	SW	240	0	B3	5
1/0	70°46.2'	150°21.4'	2788	DY	BR	-	0	B4	15
1/0	70°58.3'	150°31.1'	1434	SP	SW	260	0	B4	18
2/0	71°08.8'	151°48.6'	1729	BO	SW	270	0	B3	9


73
CHUKCHI SEA
N780
72
71
70
69
PT BARROW
LONELY
ICY CAPE
LEGEND
GW
BE
WS
BS
PN
CAPE LISBURNE
167
165
163
161
159
157
155
153

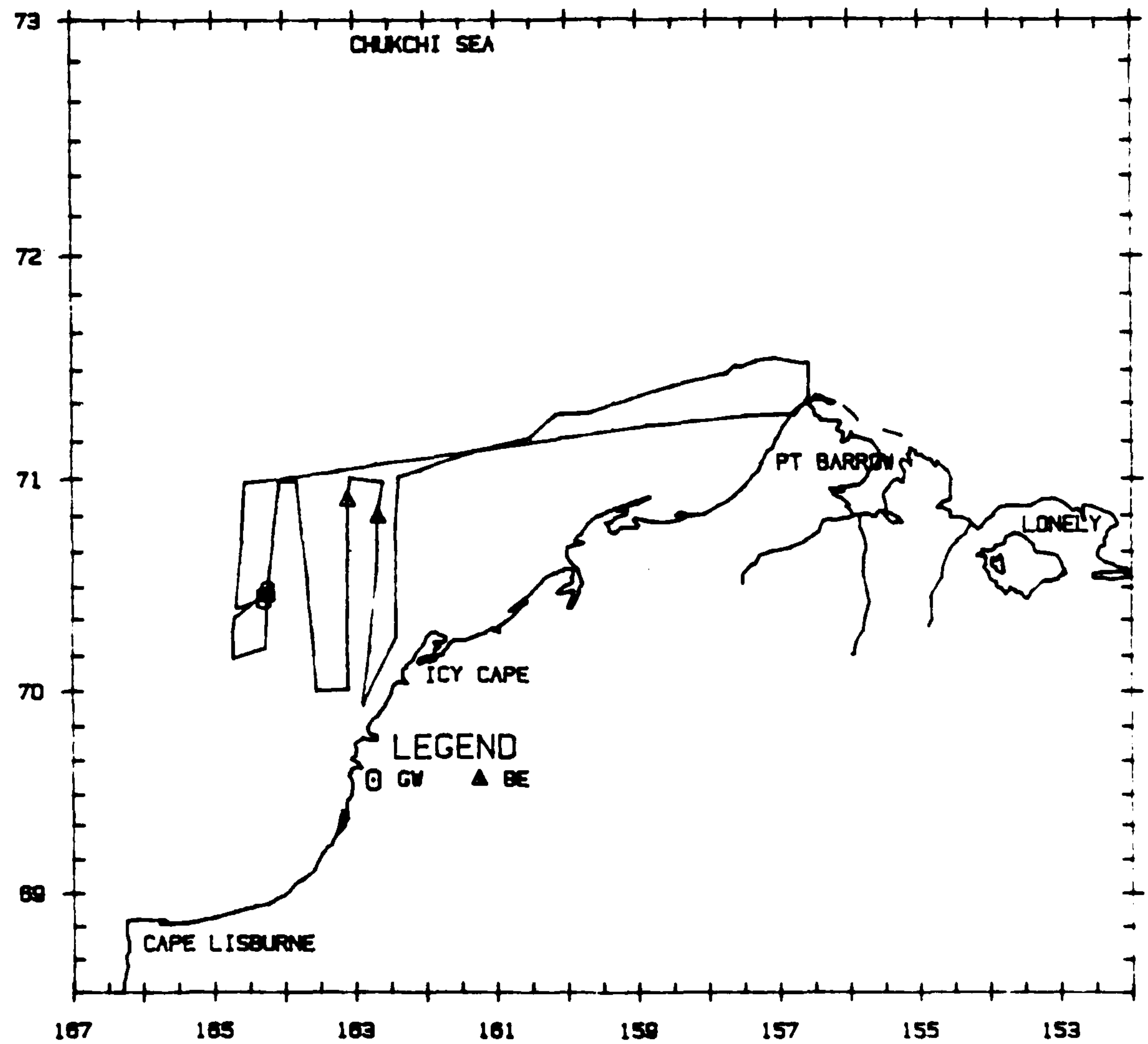

73
302EH
BEAUFORT SEA
72
71
70
69
LONELY
DEADHORSE
BARTER IS.
LEGEND
BH
155
153
151
149
147
145
143
141

N780
Flight 39: 2 October 1986

Flight was a transect survey of the western one-third of block 17 and eastern two-thirds of block 18. Weather was overcast with visibility 10 km to unlimited. Sea state was Beaufort 02 to 05 and there was no ice. Three gray whales and two dead belukhas were seen.

Gray Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	70°27.6'	164°14.4'	192	SP	RE	180	0	B3	33
1/0	78°25.8'	164°17.7'	-	BO	FE	-	0	B3	33

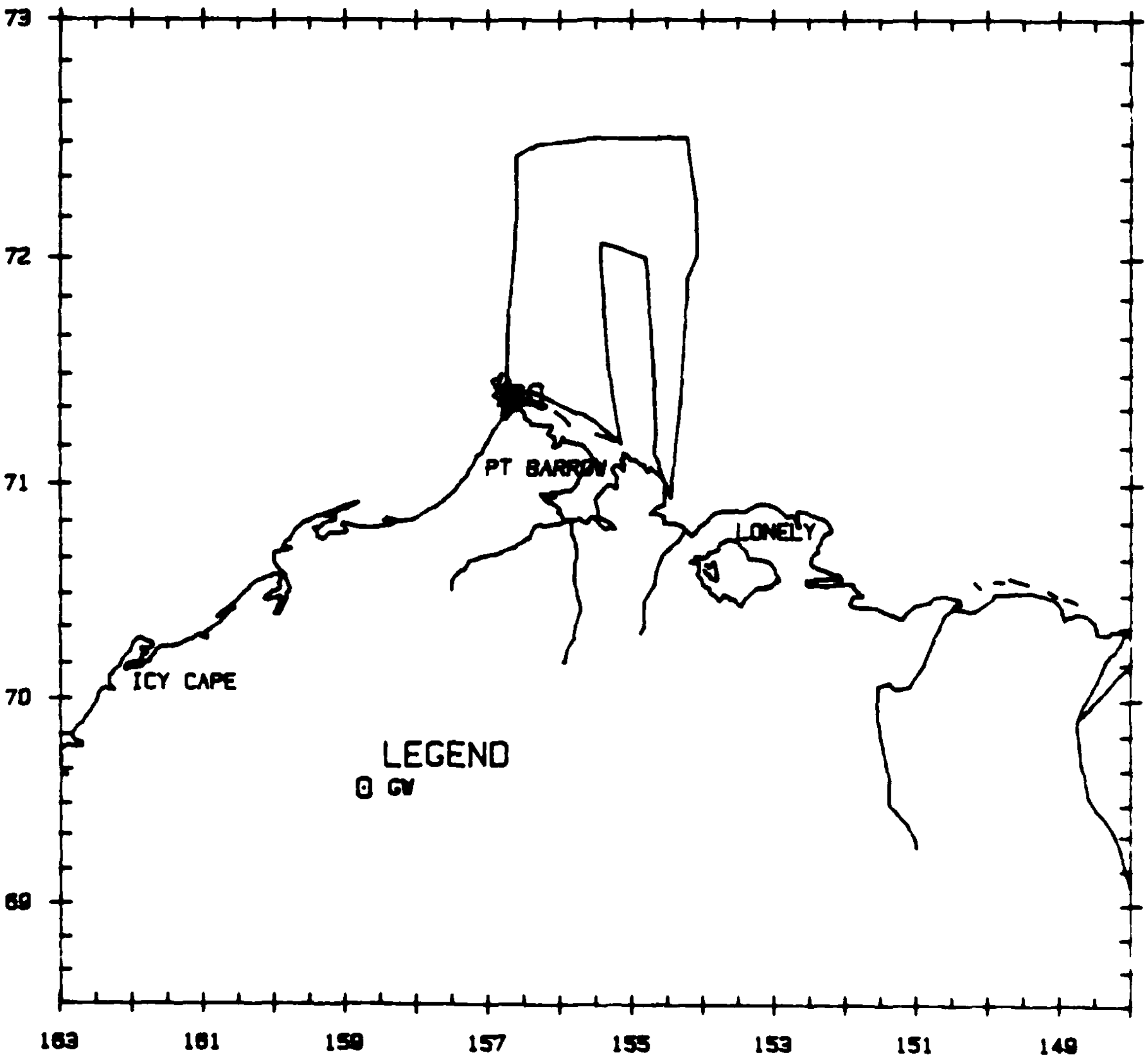

73
72
71
70
69
CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
GW
BE
CAPE LISBURNE
167
165
163
161
159
157
155
153

N780
Flight 40: 3 October 1986

Flight was a transect survey of the eastern one-half of block 12 and a search survey along 72°30'N latitude. Weather was overcast and visibility was unlimited. Sea state was Beaufort 01 to 02 and ice cover was 0 to 20 percent in block 12 and 50 to 85 percent north of there. Three gray whales were seen.

Gray Whales

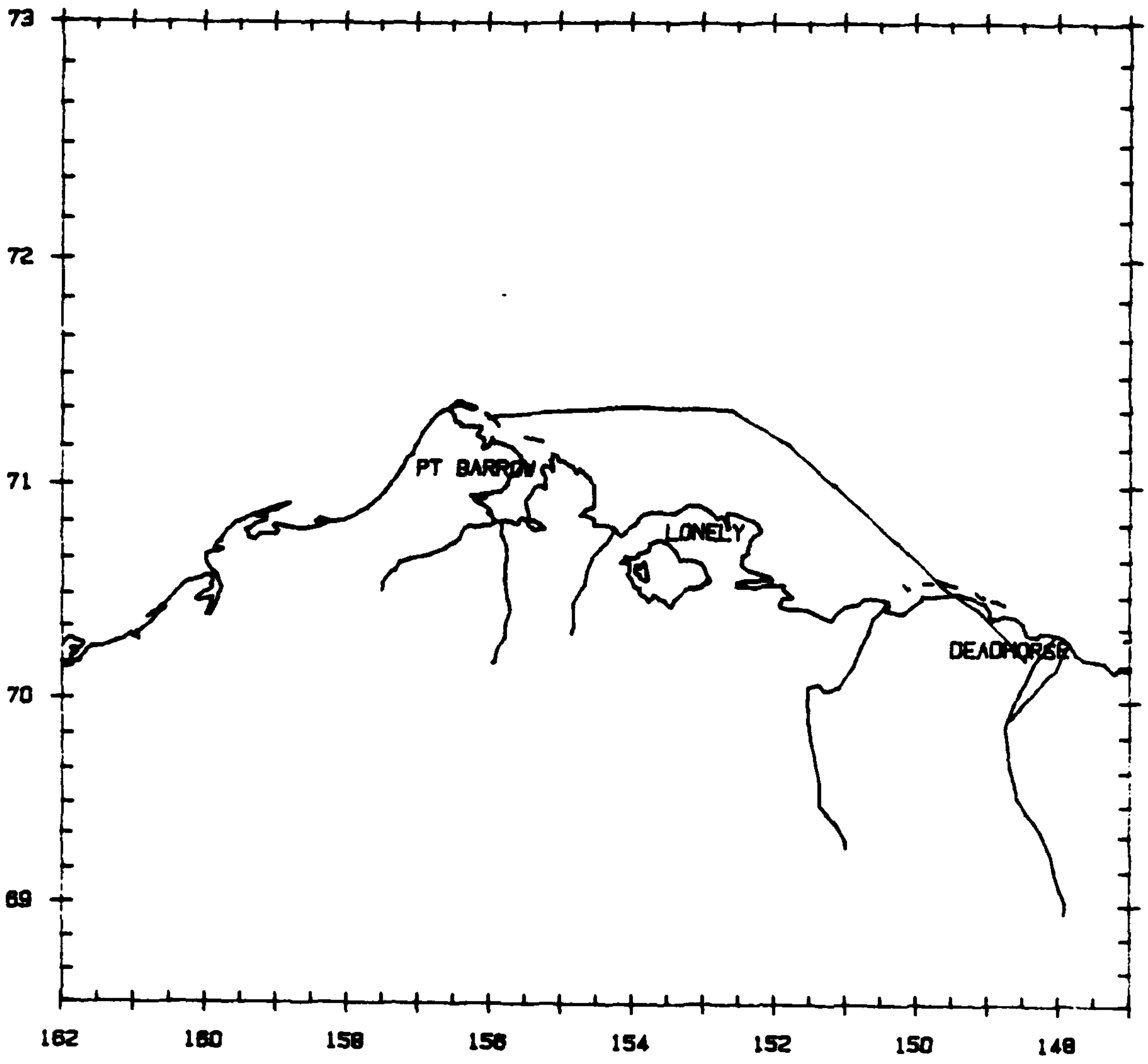
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°21.6'	156°39.0'	-	BO	NA	-	0	B2	7
1/0	71°22.9'	156°35.7'	1314	MP	FE	-	0	B2	7
1/0	71°23.4'	156°20.0'	509	MP	FE	-	0	B2	7



73
72
71
70
69
PT BARROW
LONELY
ICY CAPE
LEGEND
GW
163
161
159
157
155
153
151
149

N780
Flight 41: 5 October 1986

Flight was a transit search survey from Deadhorse to Barrow. No transect survey was attempted due to extremely poor conditions - visibility less than 2 km, low ceilings and fog, and sea states of Beaufort 06. No marine mammals were seen.



73
72
71
70
69
PT BARROW
LONELY
DEADHORSE
162
160
158
156
154
152
150
148

N780
Flight 42: 6 October 1986

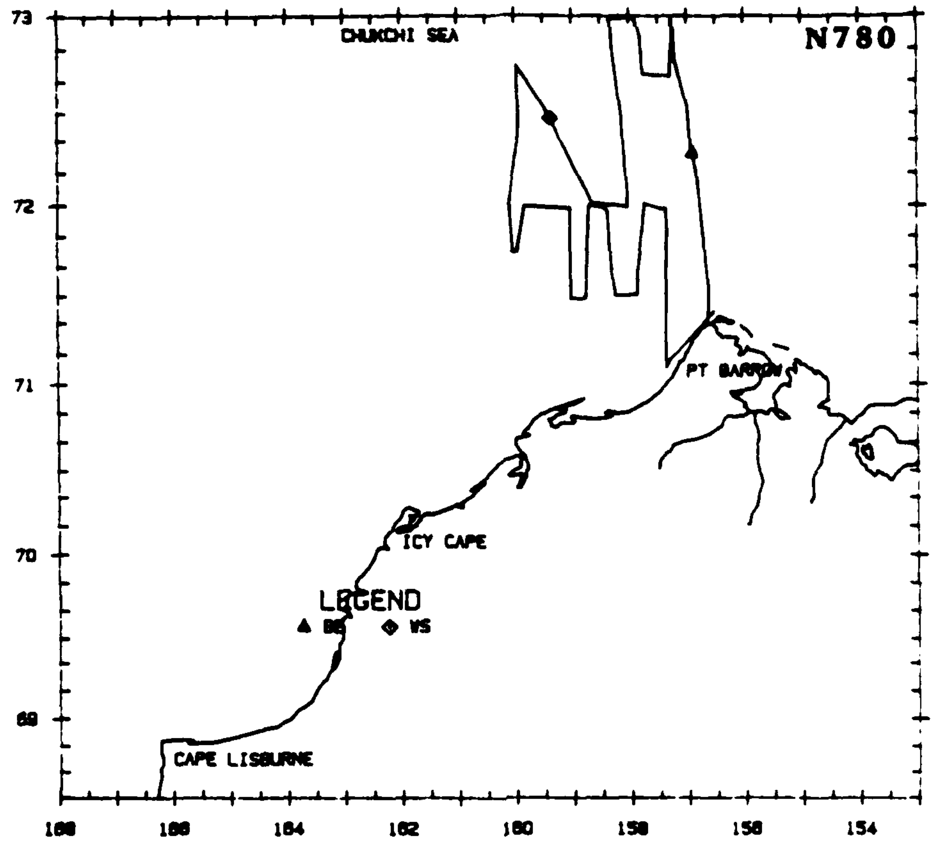
Flight was a transect survey of the northern one-half of block 13 and a modified transect survey of the ice edge north to 73°N. Weather was overcast with low ceilings and snow squalls. Visibility varied from unacceptable to 10 km. Sea state was Beaufort 03 to 06. Ice cover was 90-percent grease ice north of 72°15'N and there was no ice south of there. A belukha and a walrus were the only marine mammals seen.

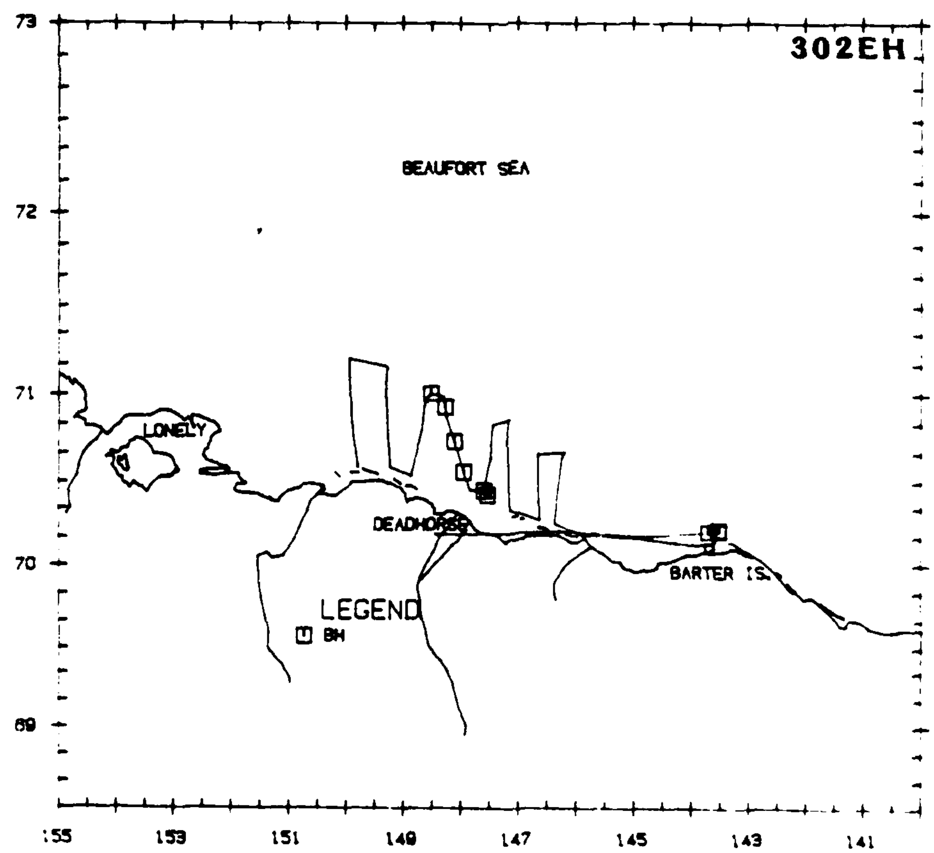
302 EH
Flight 18: 6 October 1986

Flight was a search survey to Barter Island and a transect survey of block 1. Weather was generally partly cloudy with some areas of low overcast. Visibility varied from 5 km to unlimited. There was no ice and sea state ranged from Beaufort 02 to 05. Nine bowheads, including two calves, were seen. Two bowheads were breaching.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°11.9'	143°41.9'	838	BO	SW	270	0	B3	15
1/0	70°12.7'	143°31.2'	1138	BO	BR	-	0	B3	13
1/0	70°12.0'	143°30.7'	-	BW	SW	270	0	B3	13
1/1	70°26.0'	147°35.9'	339	BO	SW	360	0	B4	15
1/1	70°24.5'	147°32.1'	-	BO	SW	130	0	B4	5
1/0	70°33.6'	147°57.2'	838	SP	SW	300	0	B3	15
1/0	70°44.1	148°06.7'	2169	BO	BR	260	0	B4	24
1/0	70°55.8'	148°16.7'	1321	SP	SW	240	0	B4	29
1/0	71°00.4'	148°31.1'	938	BO	RE	245	0	B4	48


N780
CHUKCHI SEA
PT BARROW
ICY CAPE
CAPE LISBURNE
LEGEND
BB
WS
73
72
71
70
69
154
156
158
160
162
164
166
168


302EH
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
LEGEND
BH
73
72
71
70
69
155
153
151
149
147
145
143
141

N780
Flight 43: 8 October 1986

Flight was a transect survey of block 14. Weather was overcast with low ceilings and fog. Visibility varied from unacceptable to 5 km. Sea state was Beaufort 00 to 03. Ice cover was 90 to 95 percent in the northern one-third of the block and 0 percent in the southern two-thirds. Two gray whales were seen feeding. Belukhas and walrus were also seen.

Gray Whales

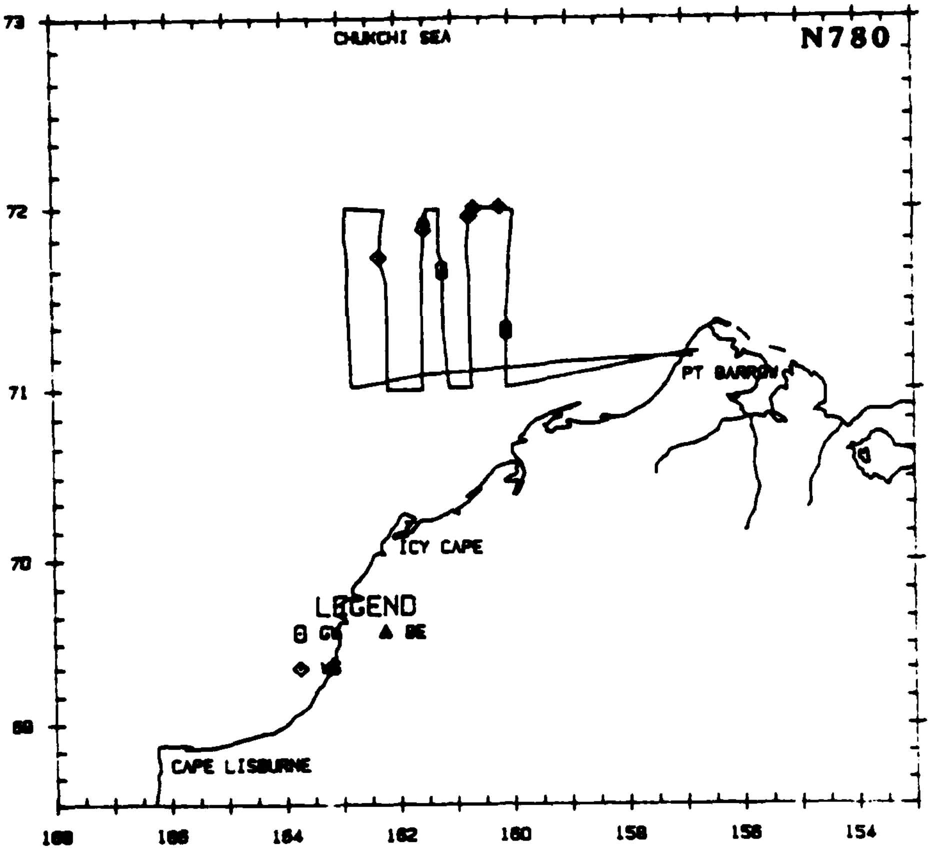
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°19.0'	160°05.7'	844	MP	FE	70	0	B3	37
1/0	71°40.0'	161°12.1'	-	MP	FE	-	0	B2	38

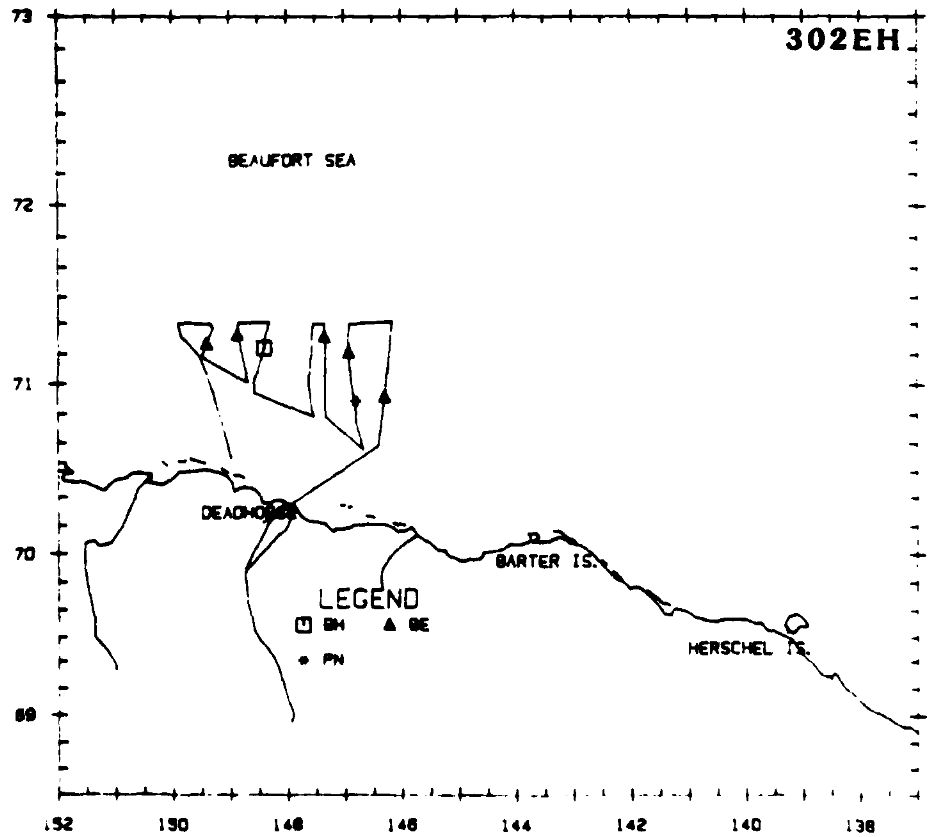
302 EH
Flight 19: 8 October 1986

Flight was a search survey through block 1 and a transect survey of block 2. Weather was overcast with patchy fog and snow squalls. Visibility varied from 1 km to unlimited. There was no ice in block 1 and conditions in block 2 ranged from 0- to 90-percent new ice. Sea state was Beaufort 00 to 04. Two bowheads were seen 100 km northwest of Deadhorse. Belukhas and an unidentified pinniped were also seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	71°12.0'	148°25.1'	523	BO	SW	90	10	B2	520


N780
CHUKCHI SEA
PT BARROW
ICY CAPE
LEGEND
CAPE LISBURNE

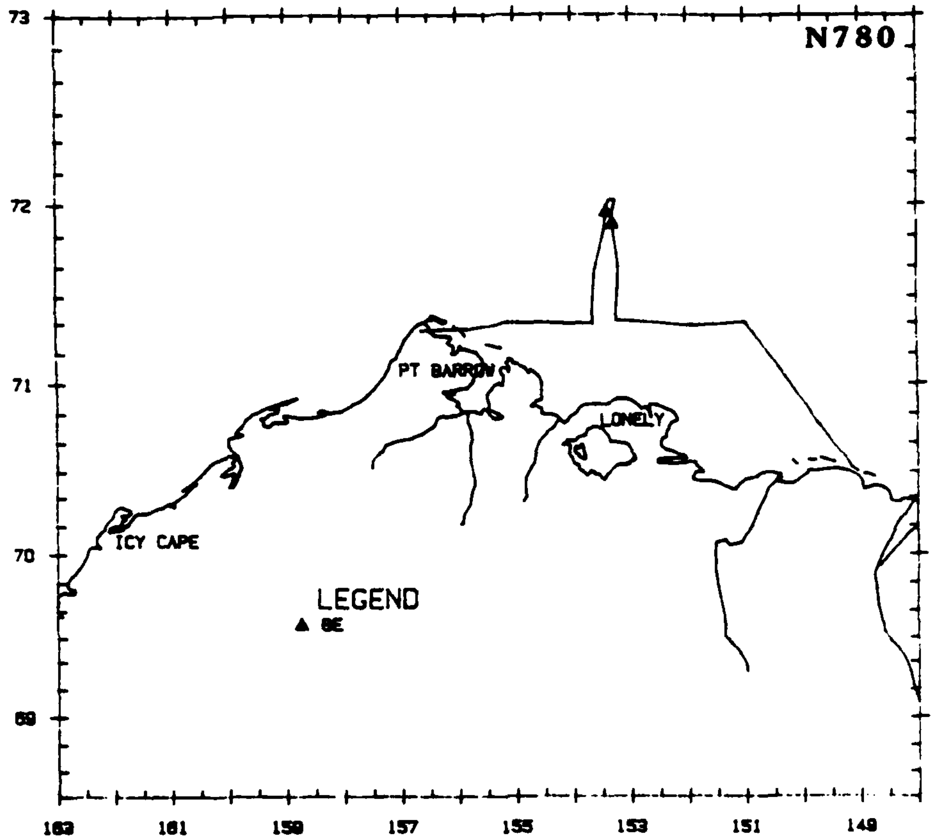

302EH
BEAUFORT SEA
BARTER IS.
LEGEND
BH
BE
PN
HERSCHEL IS.

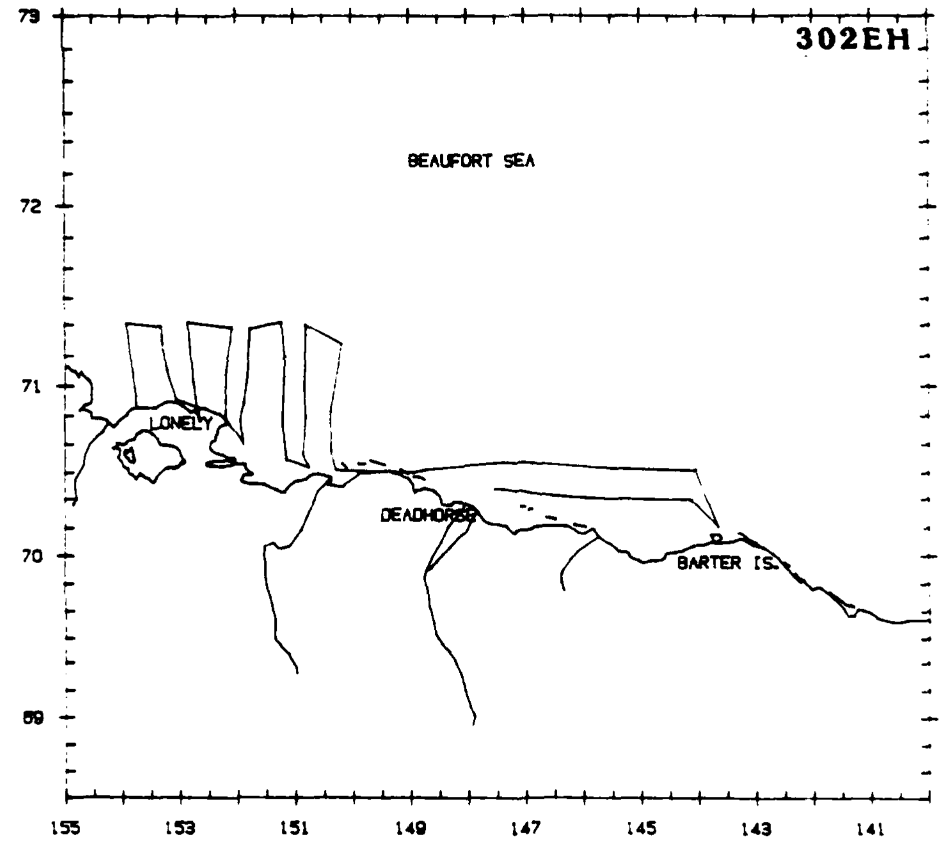
N780
Flight 44: 9 October 1986

Flight was a transect survey of the western one-quarter of block 11. Weather was overcast with fog and snow squalls, and visibility varied from 1 to 10 km. Ice cover was 75 to 90 percent north of 71°45N, and there was no ice south of there. Sea state varied from Beaufort 03, in the heavily iced areas, to 06 in the open-water areas. Belukhas were the only marine mammals seen.

302 EH
Flight 20: 9 October 1986

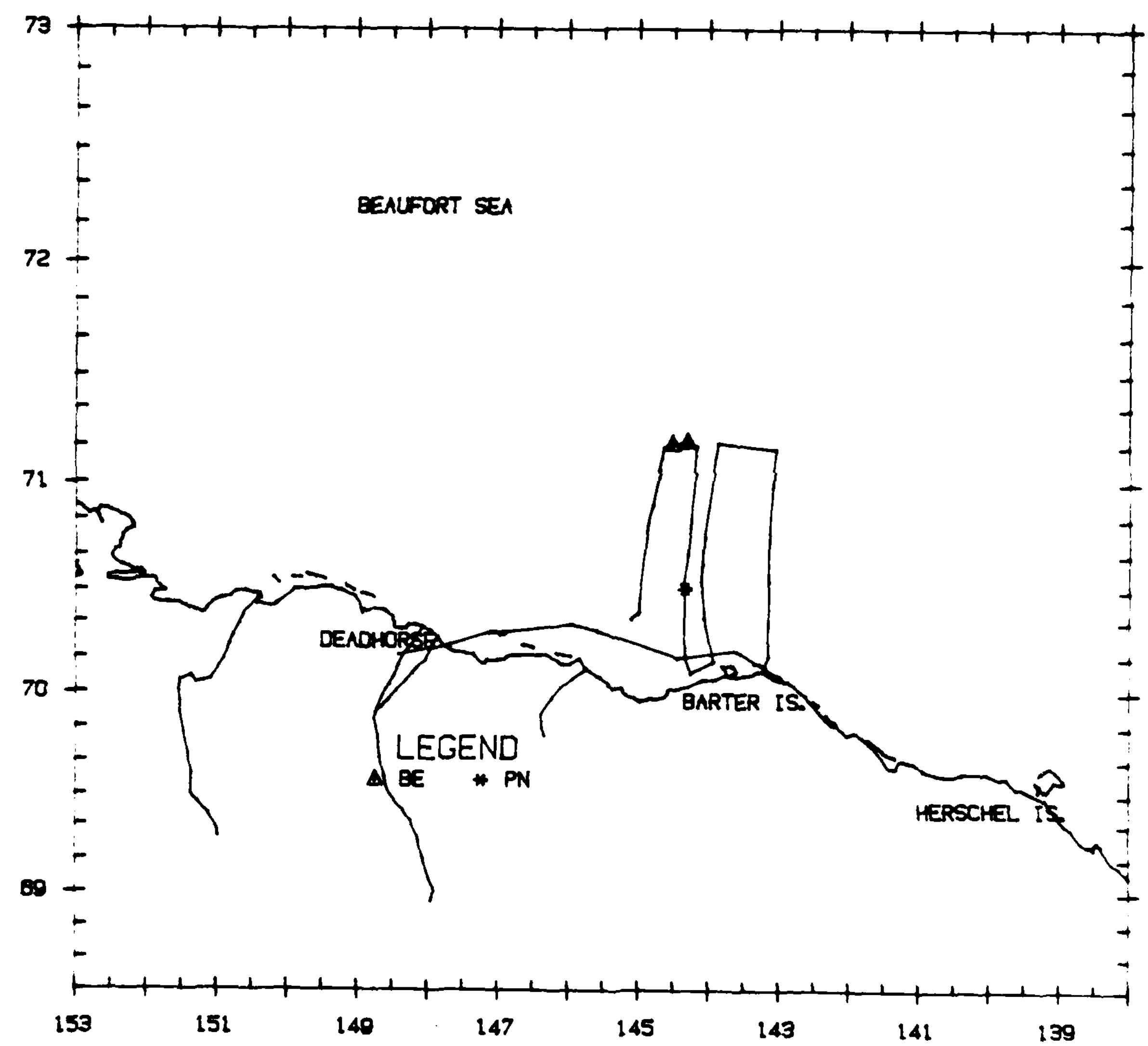
Flight was a search survey to Barter Island, followed by a transect survey of block 3. Weather was overcast with patches of fog east of Deadhorse, and mostly clear west of Deadhorse. Visibility varied from 1 km to unlimited. Ice cover ranged from 0 to 10 percent and sea state was Beaufort 02 to 05. No marine mammals were seen.


N780
PT BARROW
LONELY
ICY CAPE
LEGEND
▲ BE
73
72
71
70
69
163
161
159
157
155
153
151
149


302EH
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
73
72
71
70
69
155
153
151
149
147
145
143
141

302 EH
Flight 21: 10 October 1986

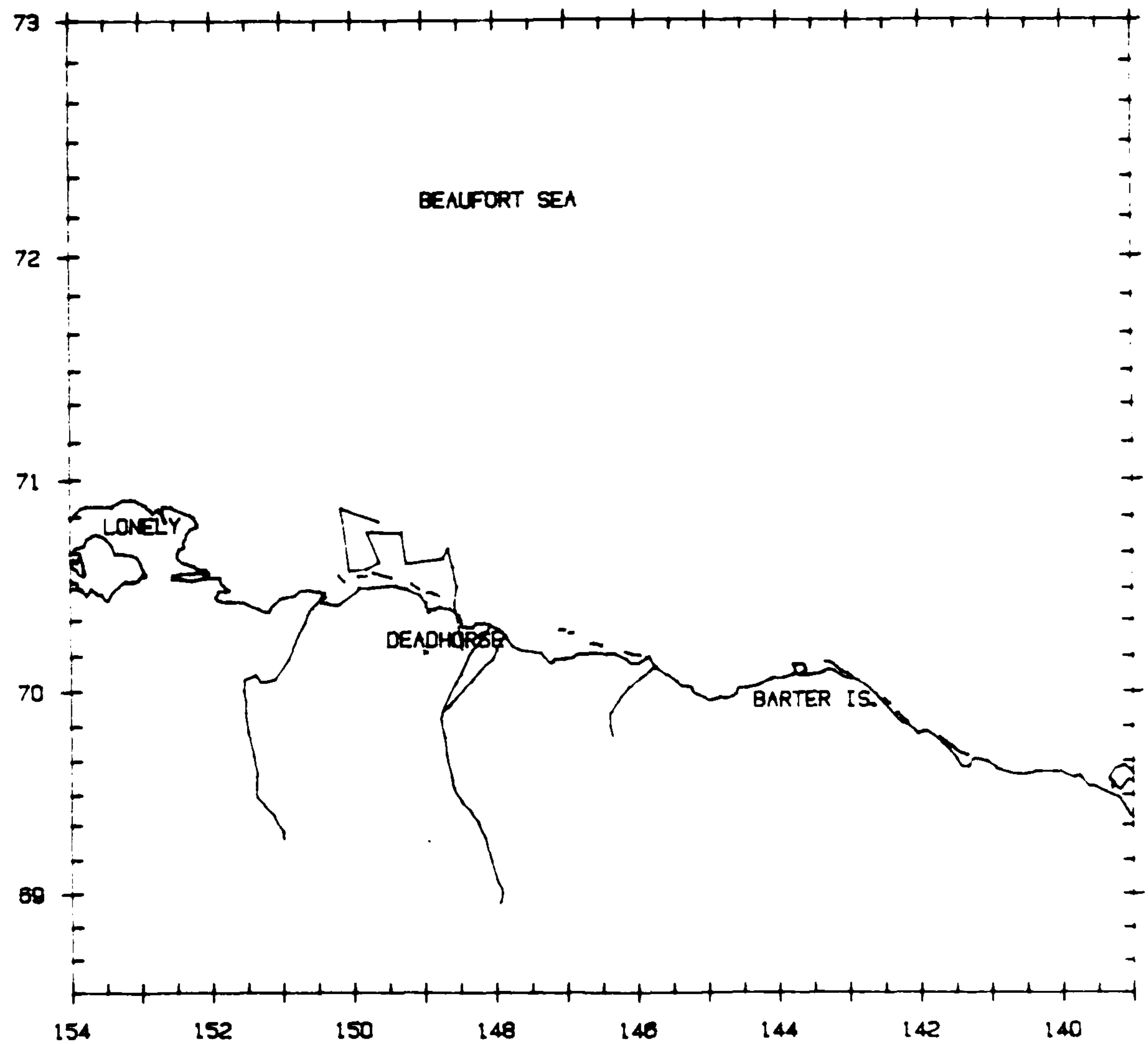
Flight was a search survey to Barter Island and a transect survey of the eastern two-thirds of blocks 4 and 6. Weather was overcast with low fog to the west that caused the survey to be curtailed. Ice cover was 40 to 95 percent in block 6 and 0 to 40 percent in block 4. Sea state was Beaufort 00 to 02. Belukhas and unidentified pinnipeds were seen.



73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BE
PN
153
151
149
147
145
143
141
139

302 EH
Flight 22: 11 October 1986

Flight was a transect survey of block 1. Low-lying fog offshore caused the survey to be aborted. Visibility varied from unlimited to unacceptable. There was no ice seaward of the barrier islands and sea state ranged from Beaufort 01 to 05. No marine mammals were seen.

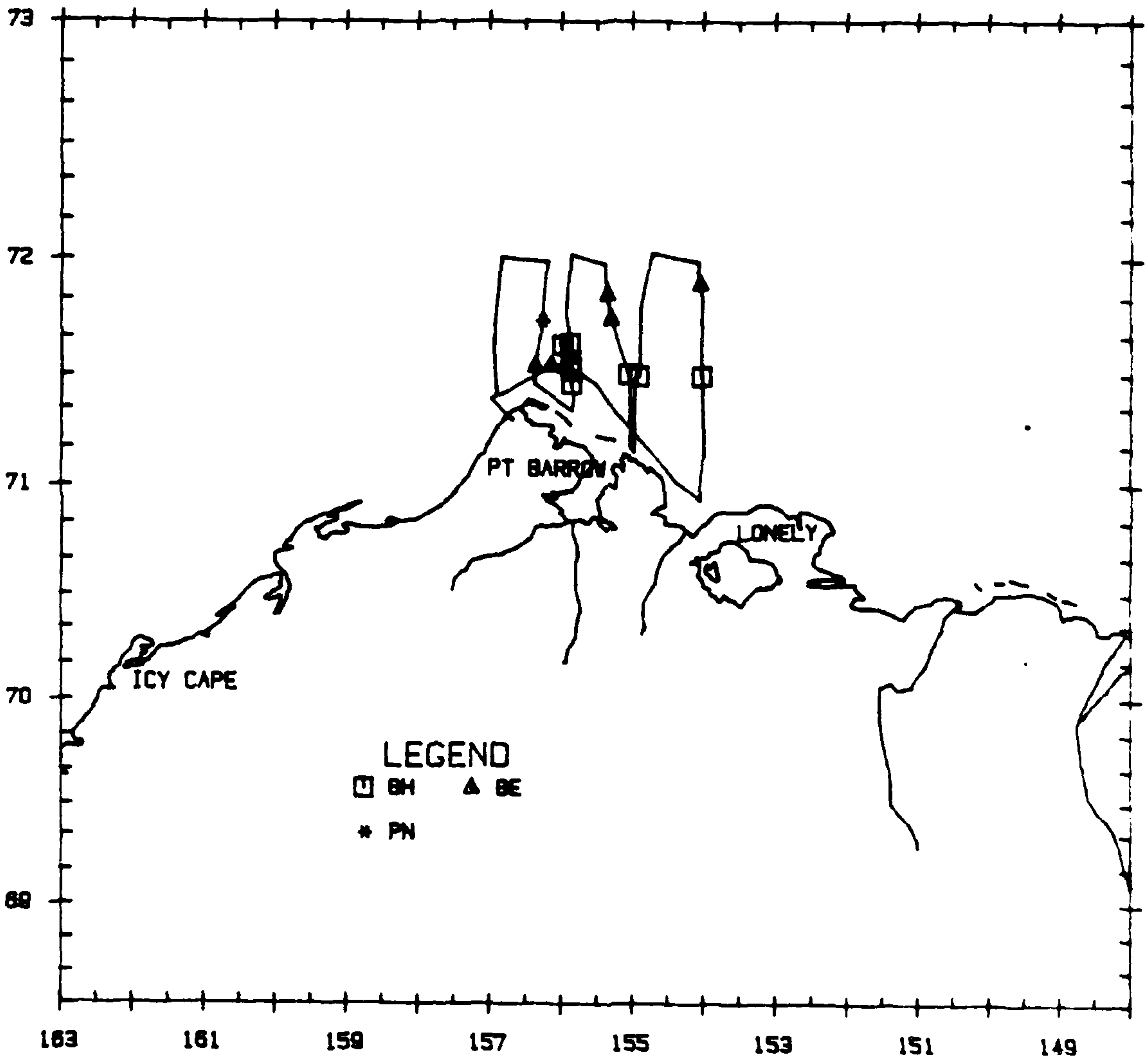

BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
73
72
71
70
69
154
152
150
148
146
144
142
140

N780
Flight 45: 12 October 1986

Flight was a transect survey of block 12. Weather was partly cloudy with some fog and visibility varied from 2 km to unlimited. Sea state was Beaufort 01 to 04 and there was no ice, except in the northernmost area where cover was 90 percent. Eleven bowheads were seen, including two cow-calf pairs. Belukhas and unidentified pinnipeds were also seen.

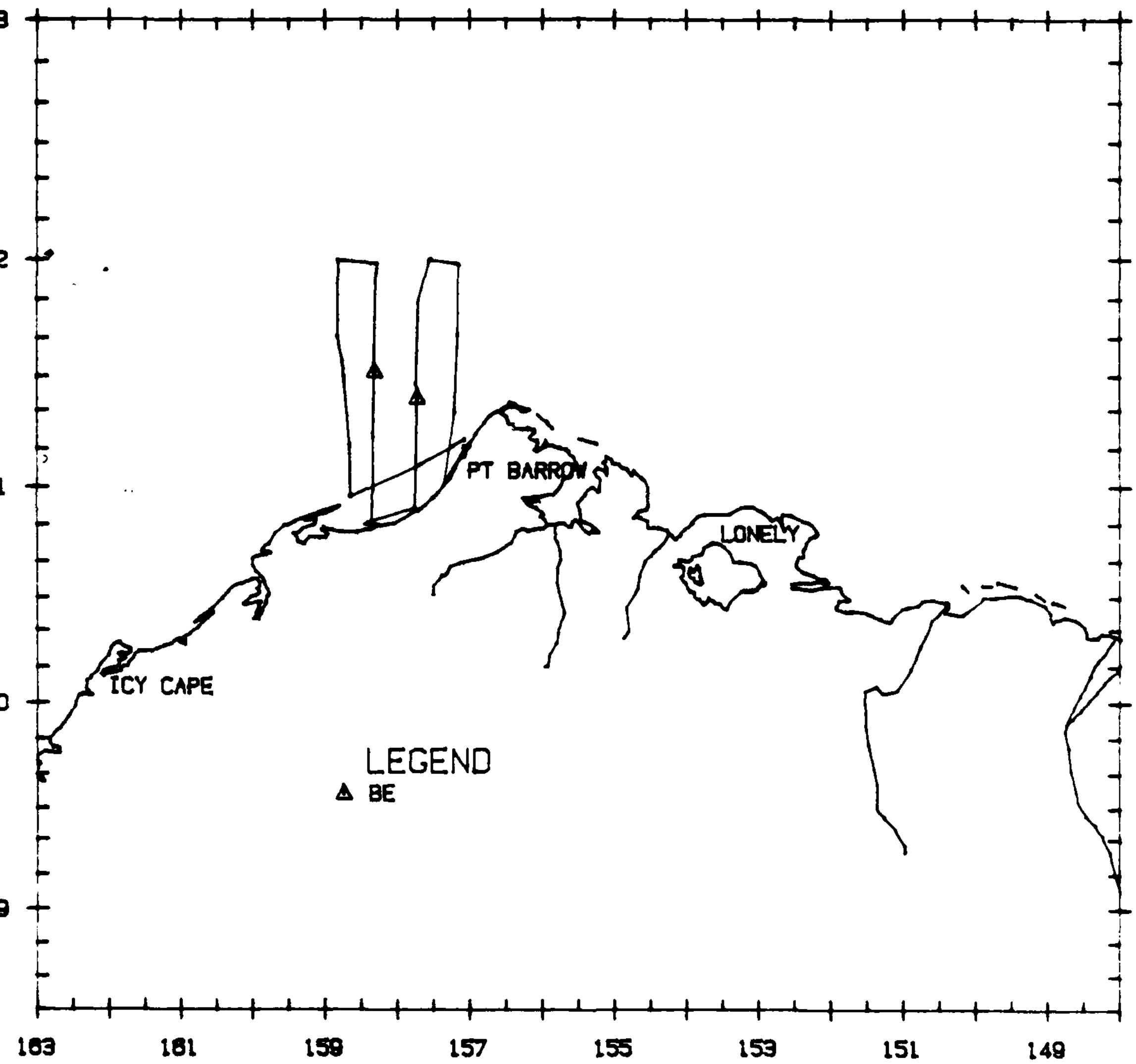
Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°28.2'	154°01.8'	288	BO	SW	240	0	B2	31
1/0	71°28.1'	154°54.7'	948	BO	SW	250	0	B2	18
1/0	71°28.6'	155°03.8'	993	BO	SW	270	0	B2	13
2/1	71°38.3'	155°52.6	3600	BW	C/C	230	0	B3	154
2/1	71°37.7'	155°59.0'	-	BW	C/C	230	0	B3	154
1/0	71°32.2'	155°52.4'	2080	BW	SW	240	0	B3	18
2/0	71°31.0'	155°52.6'	1396	BO	SW	300	0	B3	18
1/0	71°26.2'	155°51.8'	233	BO	SW	290	0	B3	5


73
72
71
70
69
163
161
159
157
155
153
151
149
PT BARROW
LONELY
ICY CAPE
LEGEND
BH
BE
PN

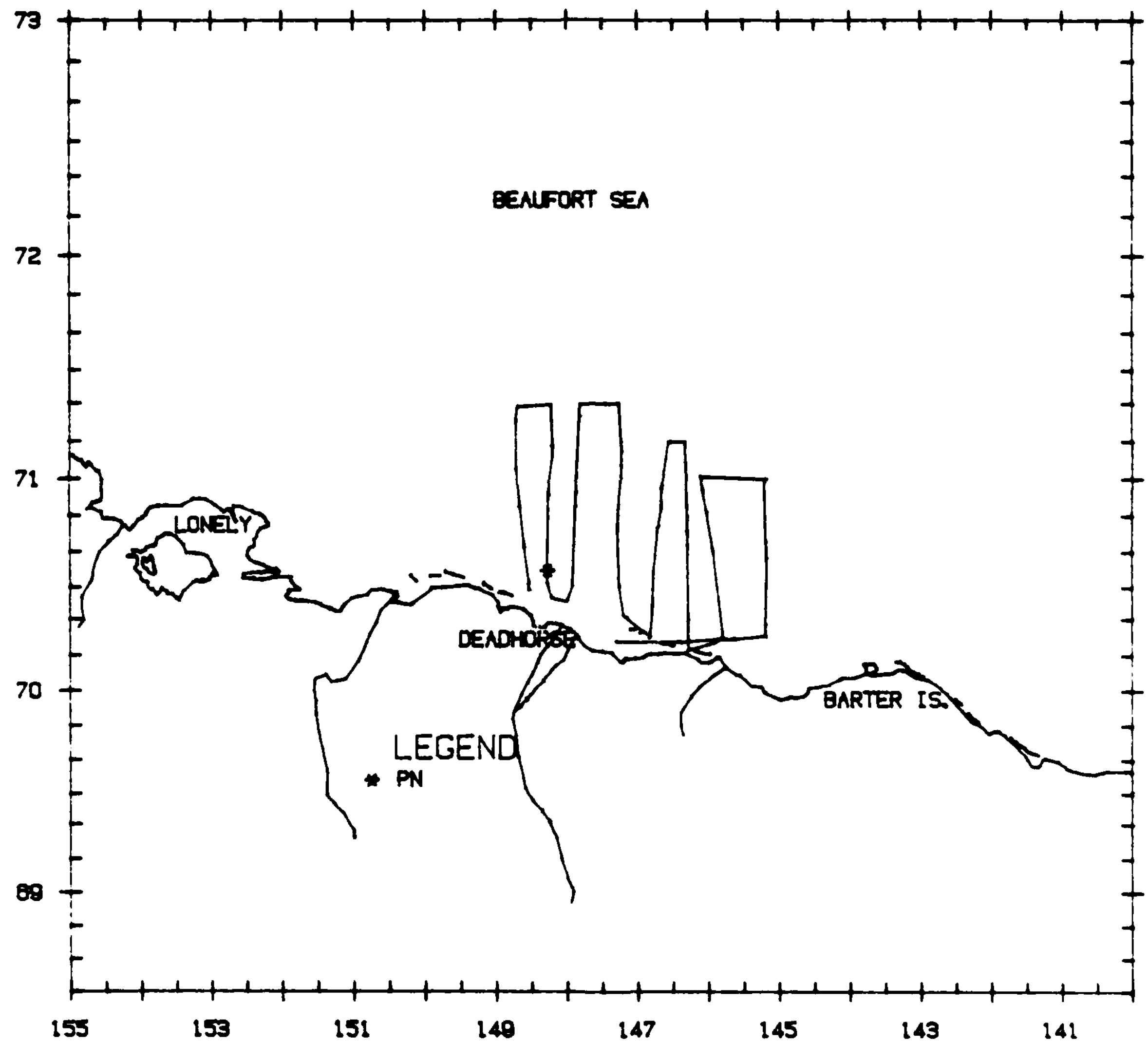
N780
Flight 46: 13 October 1986

Flight was a transect survey of the eastern two-thirds of block 13. Weather was overcast with fog and visibility varied from 2 km to unlimited. Ice cover was 0 to 40 percent and sea state was Beaufort 03 to 07. Belukhas were the only marine mammals seen.


73
72
71
70
69
163
161
159
157
155
153
151
149
PT BARROW
LONELY
ICY CAPE
LEGEND
BE

302 EH
Flight 23: 14 October 1986

Flight was a transect survey of the eastern three-fourths of blocks 1 and 2 and the western one-third of blocks 4 and 6. Weather was low overcast and visibility varied from 1 km to unlimited. Ice cover ranged from 0 to 95 percent. Sea state was Beaufort 00 to 04. One unidentified pinniped was seen.


73
72
71
70
69
155
153
151
149
147
145
143
141
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
LEGEND
* PN

N780
Flight 47: 15 October 1986

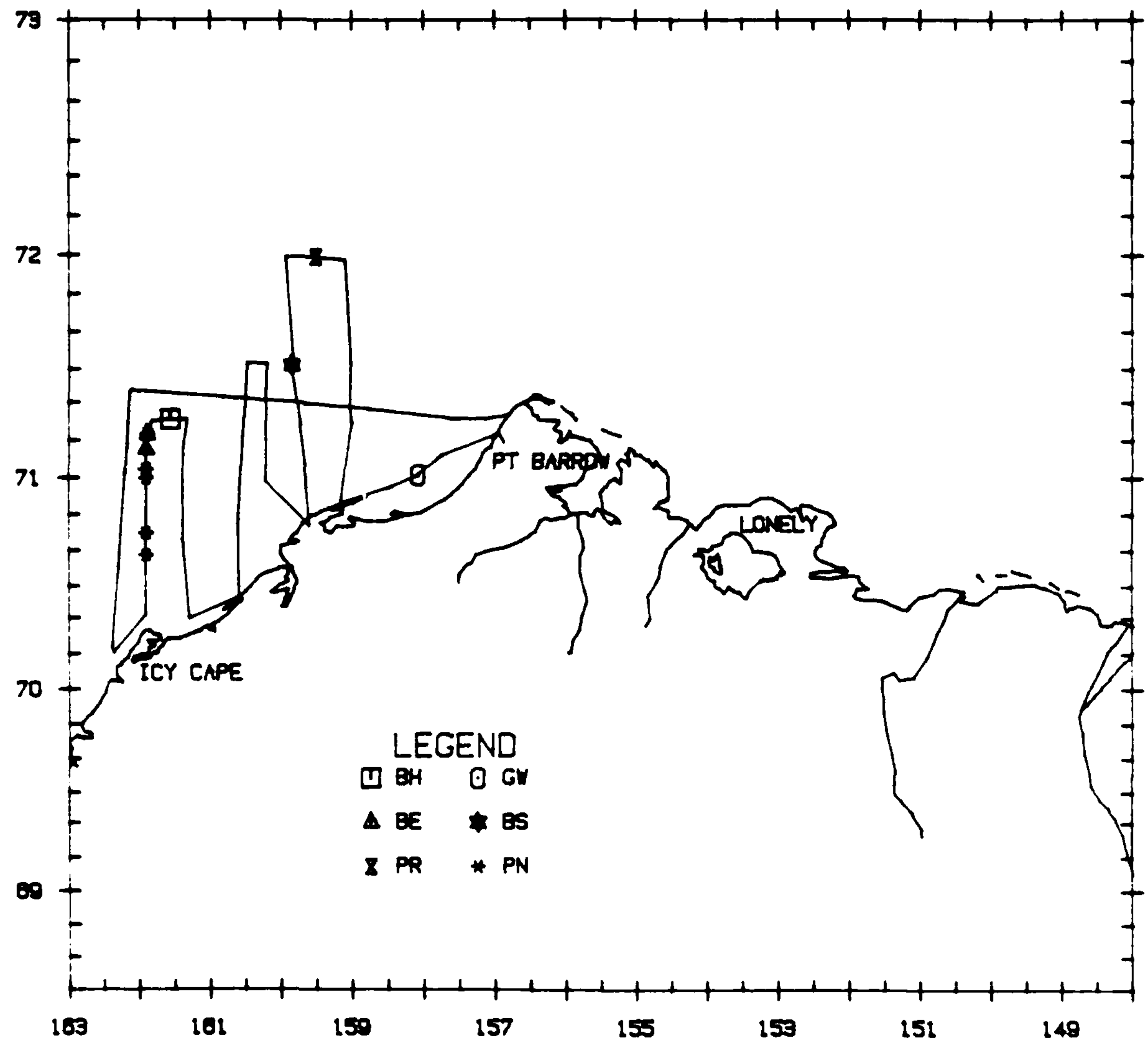
Flight was a transect survey of the western one-third of block 13 and portions of blocks 14 and 17. Weather was overcast with low ceilings, fog, and snow squalls. Visibility was 2 to 5 km. Ice cover was 70 to 90 percent in the northern two-thirds of blocks 13 and 14, and 0 to 40 percent in the remaining areas surveyed. Sea state was Beaufort 00 to 02. One bowhead was seen swimming and one gray whale was seen feeding. Belukhas, unidentified pinnipeds, a bearded seal, a polar bear, and a dead walrus were also seen.

Bowhead Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°15.7'	161°34.2'	-	BO	SW	210	80	B1	38

Gray Whale

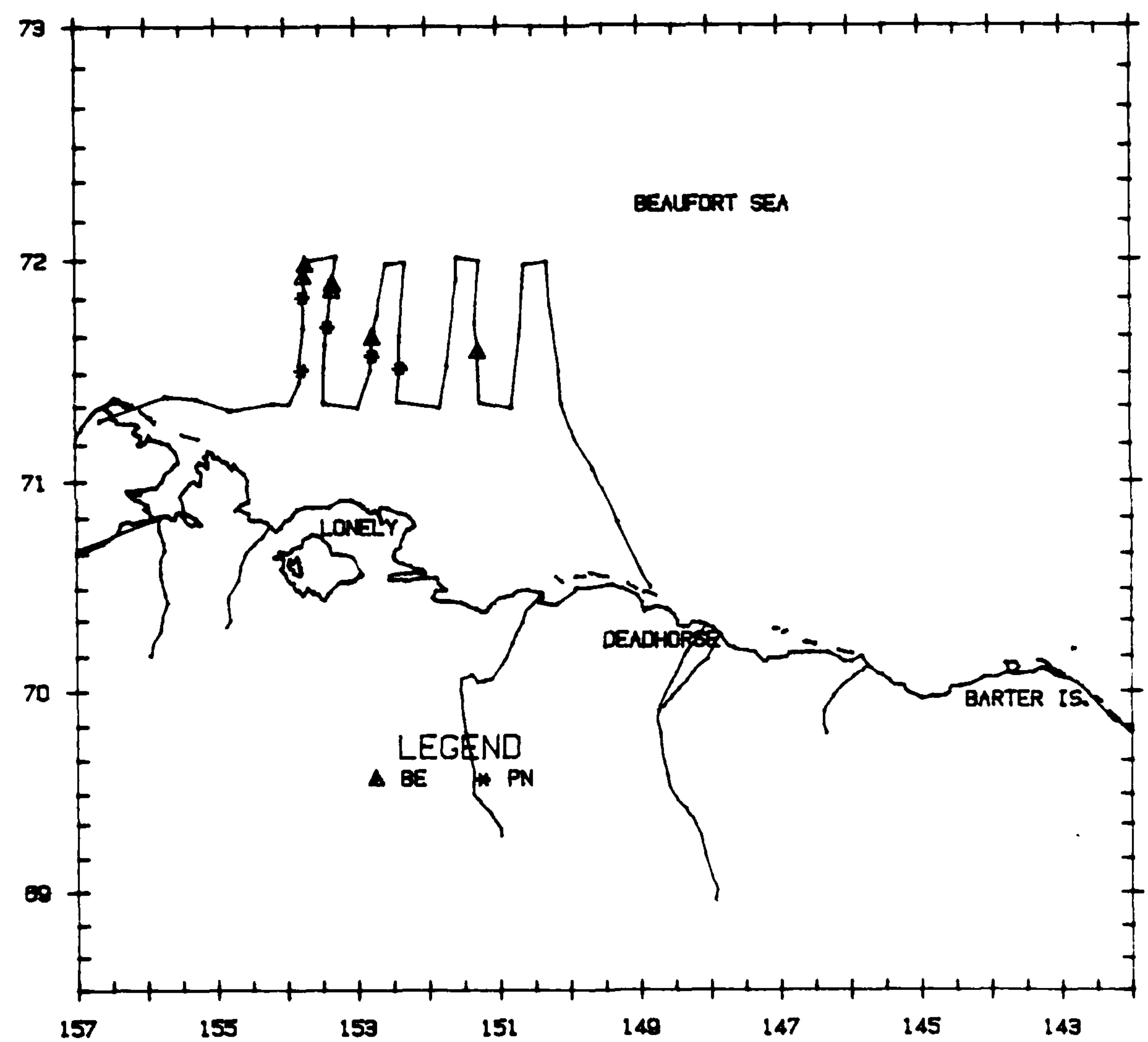
T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°00.8'	158°04.9'	-	SP	FE	-	0	B2	20



73
72
71
70
69
163
161
159
157
155
153
151
149
PT BARROW
LONELY
ICY CAPE
LEGEND
BH
GW
BE
BS
PR
PN

N780
Flight 48: 16 October 1986

Flight was a transect survey of block 11. Weather was overcast with fog and visibility was 1 km to unlimited. Ice cover was 0 to 45 percent in the southwestern one-quarter and 70 to 99 percent in all other areas. Sea state was Beaufort 00 to 02. Belukhas and unidentified pinnipeds were seen.



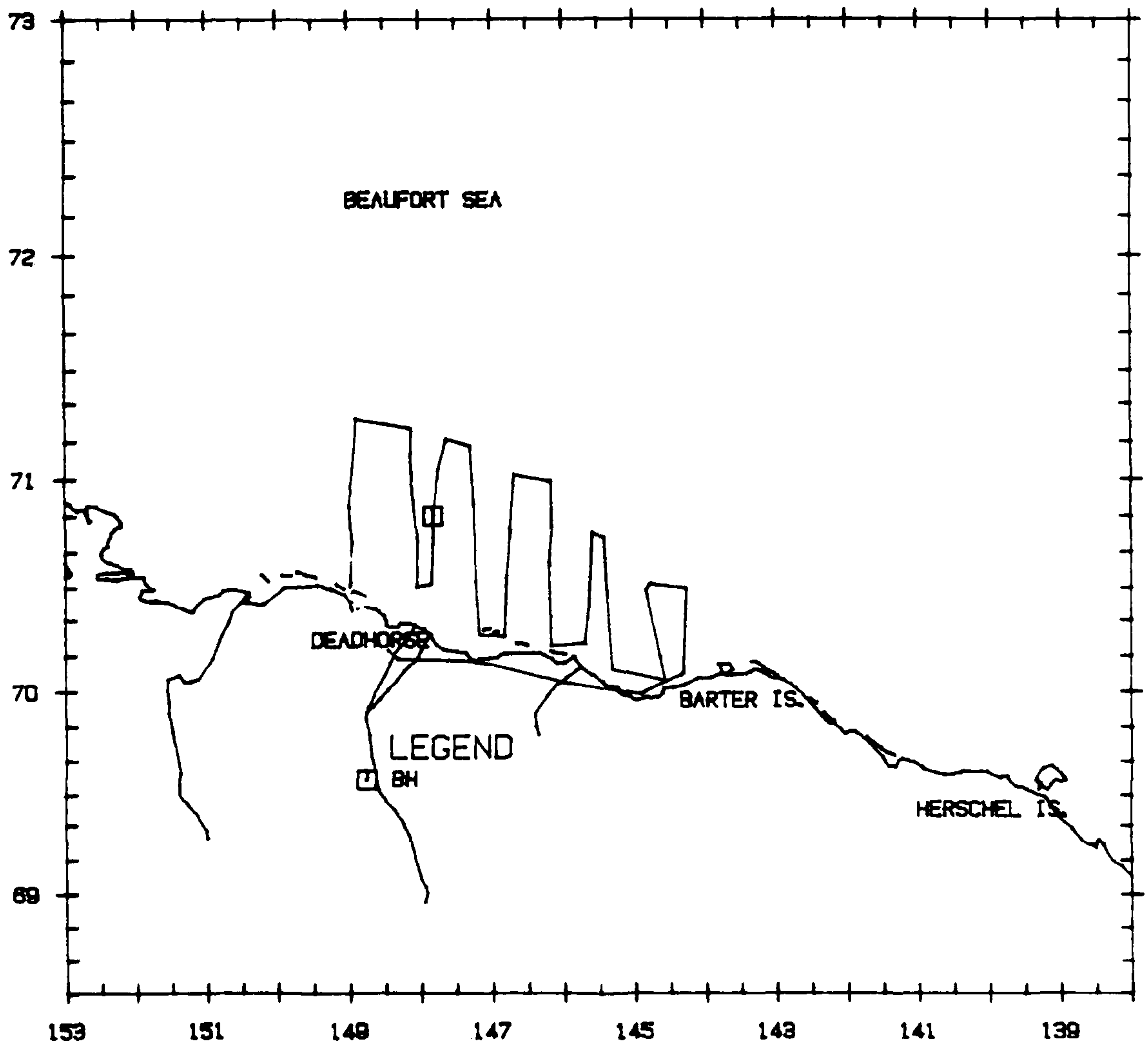
73
72
71
70
69
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
LEGEND
▲ BE
✱ PN
157
155
153
151
149
147
145
143

N780
Flight 49: 17 October 1986

Flight was a transect survey of the western two-thirds of block 4, eastern three-quarters of block 1, and portions of block 2. Weather was overcast and visibility unlimited. Ice cover was 90 to 99 percent in blocks 4 and 2 and there was no ice in block 1. Sea state was Beaufort 00 to 02. One bowhead was seen swimming west.

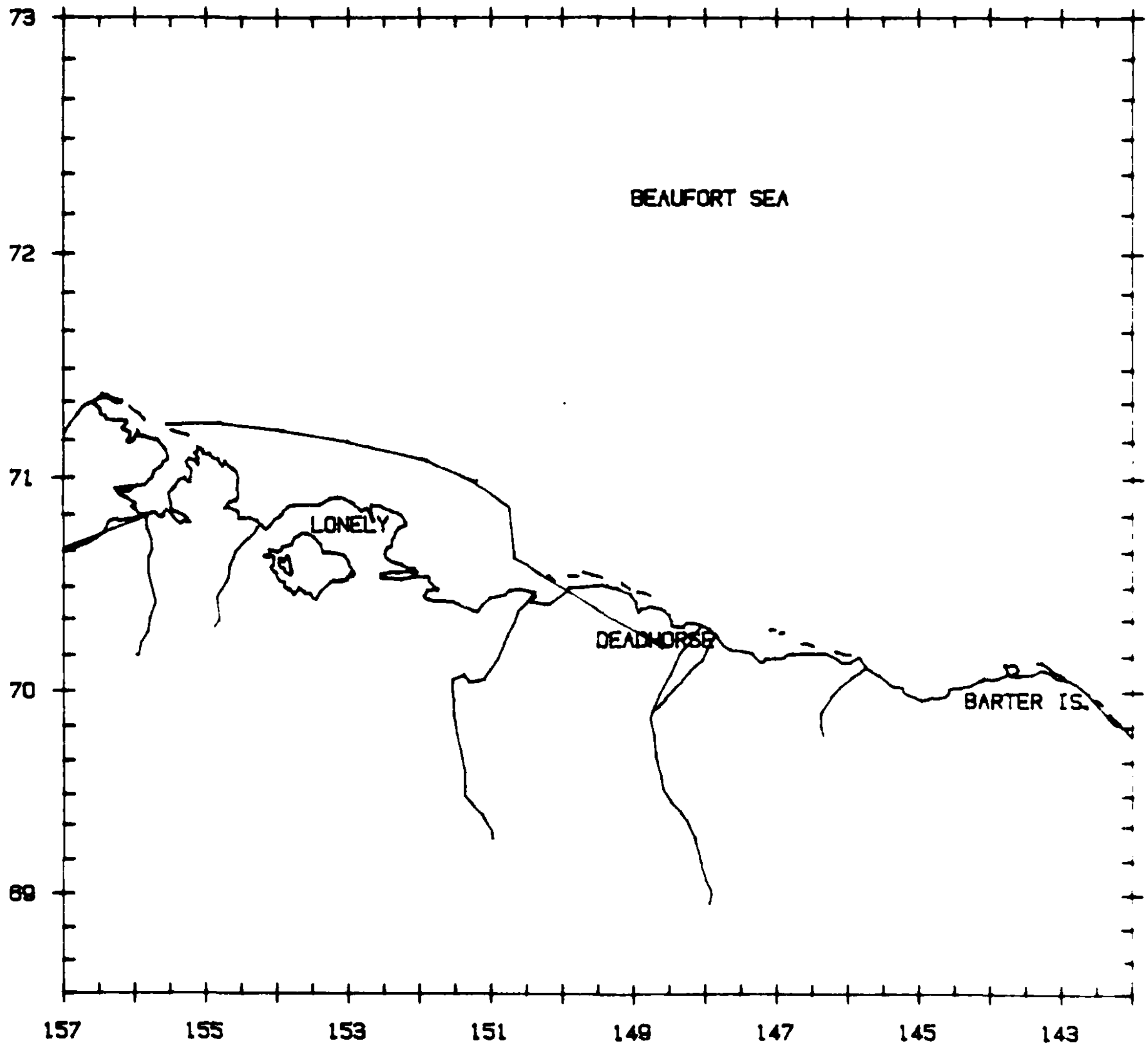
Bowhead Whale

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°49.9'	147°48.3'	1240	BW	SW	270	10	B2	38


73
72
71
70
69
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BH
153
151
149
147
145
143
141
139

N780
Flight 50: 18 October 1986

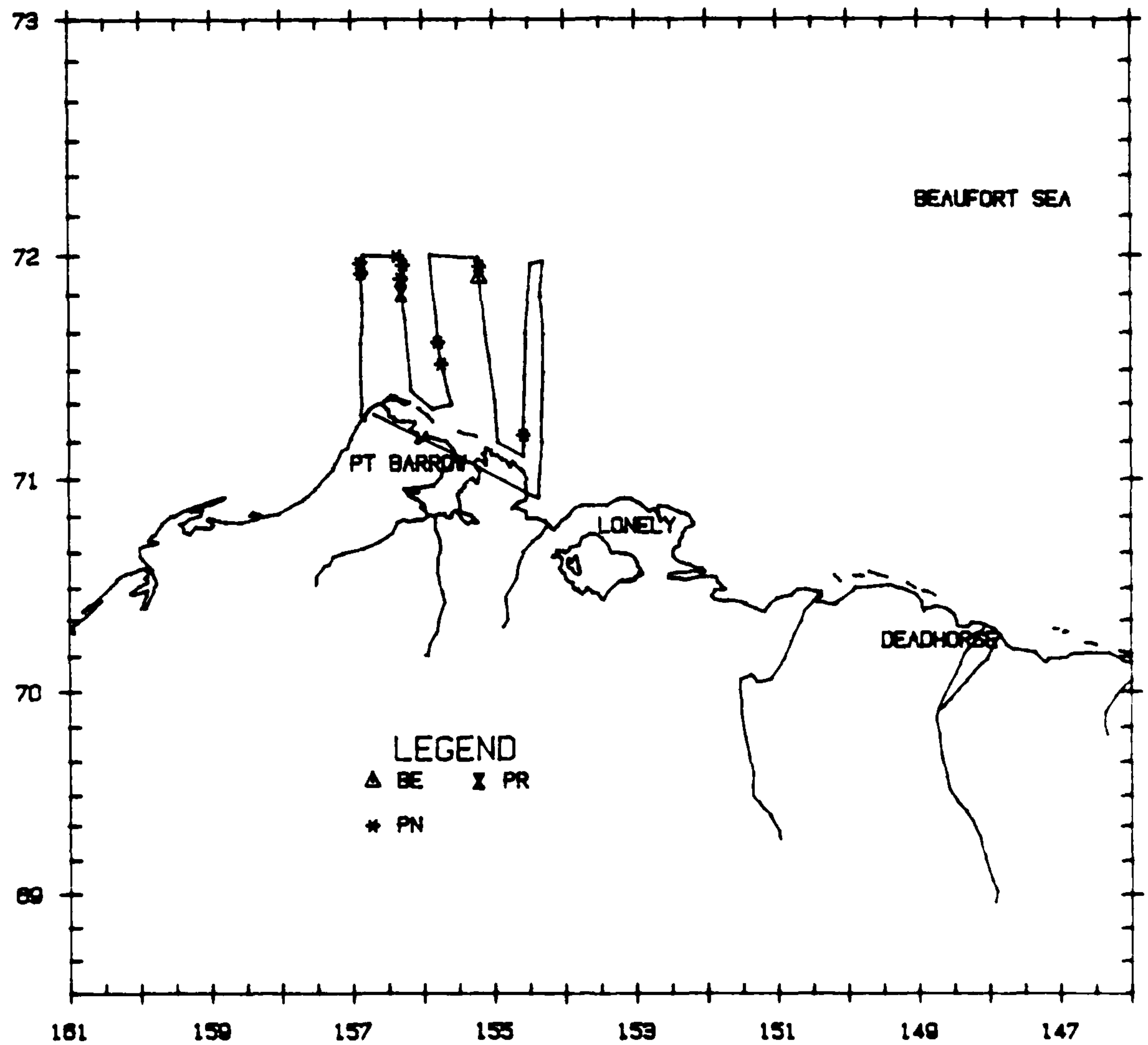
Flight was a transit from Deadhorse to Barrow. No transect survey was flown due to the adverse weather conditions: low ceiling, fog, snow squalls, and high winds (>30 kns). Sea state was Beaufort 03 to 07. Ice cover varied from 0 to 99 percent. No marine mammals were seen.



73
72
71
70
69
BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
157
155
153
151
149
147
145
143

N780
Flight 51: 19 October 1986

Flight was a transect survey of block 12. Weather was overcast with low ceilings, fog, and visibility varied from 1 km to unlimited. Ice cover was mostly 90- to 99-percent new ice, with some completely open water areas. Sea state was Beaufort 00 to 01. Belukhas, unidentified pinnipeds, and one polar bear were seen.


73
72
71
70
69
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
LEGEND
BE
PR
PN
161
159
157
155
153
151
149
147

N780
Flight 52: 20 October 1986

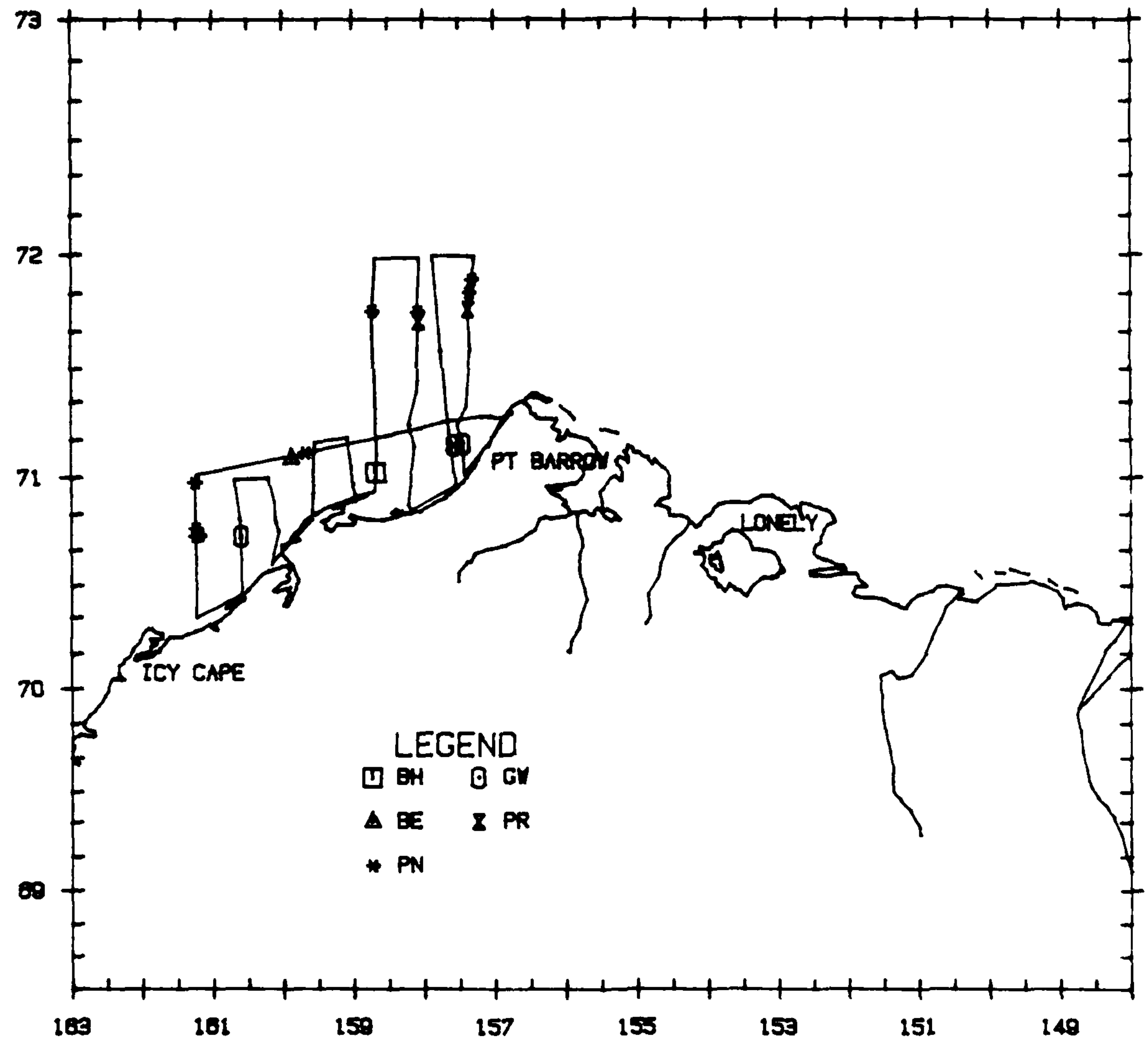
Flight was a transect survey of the eastern two-thirds of block 13 and eastern one-half of block 17. Weather was clear to overcast with some fog and snow squalls. Visibility varied from 3 km to unlimited. Ice cover was 95 to 99 percent in the northern three-quarters of block 13 and northern one-third of block 17, and 0 to 10 percent in the remaining areas. Sea state was Beaufort 00 to 01. Two bowheads were seen in block 13. Six gray whales were seen, mostly feeding. Belukhas, polar bears, and unidentified pinnipeds were also seen.

Bowhead Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	71°01.3'	158°41.0'	-	BW	SW	-	50	B2	26

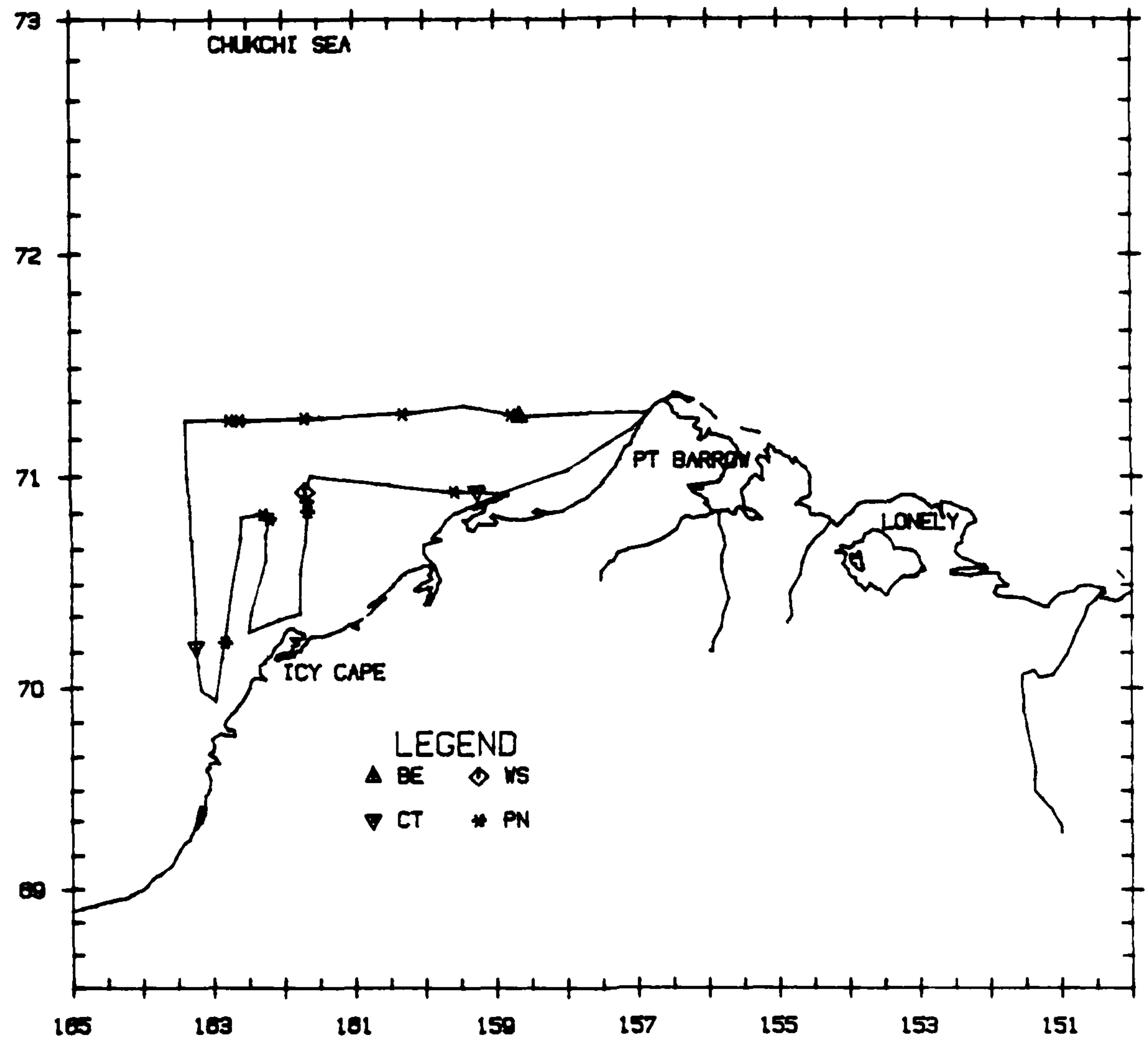
Gray Whales

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°08.9'	157°27.2'	-	MP	FE	-	0	B2	29
4/0	71°08.5'	157°35.0'	-	MP	FE	-	0	B2	29
1/0	70°43.9'	160°36.7'	-	BO	SW	360	0	B2	20


73
72
71
70
69
163
161
159
157
155
153
151
149
PT BARROW
LONELY
ICY CAPE
LEGEND
BH
GW
BE
PR
PN

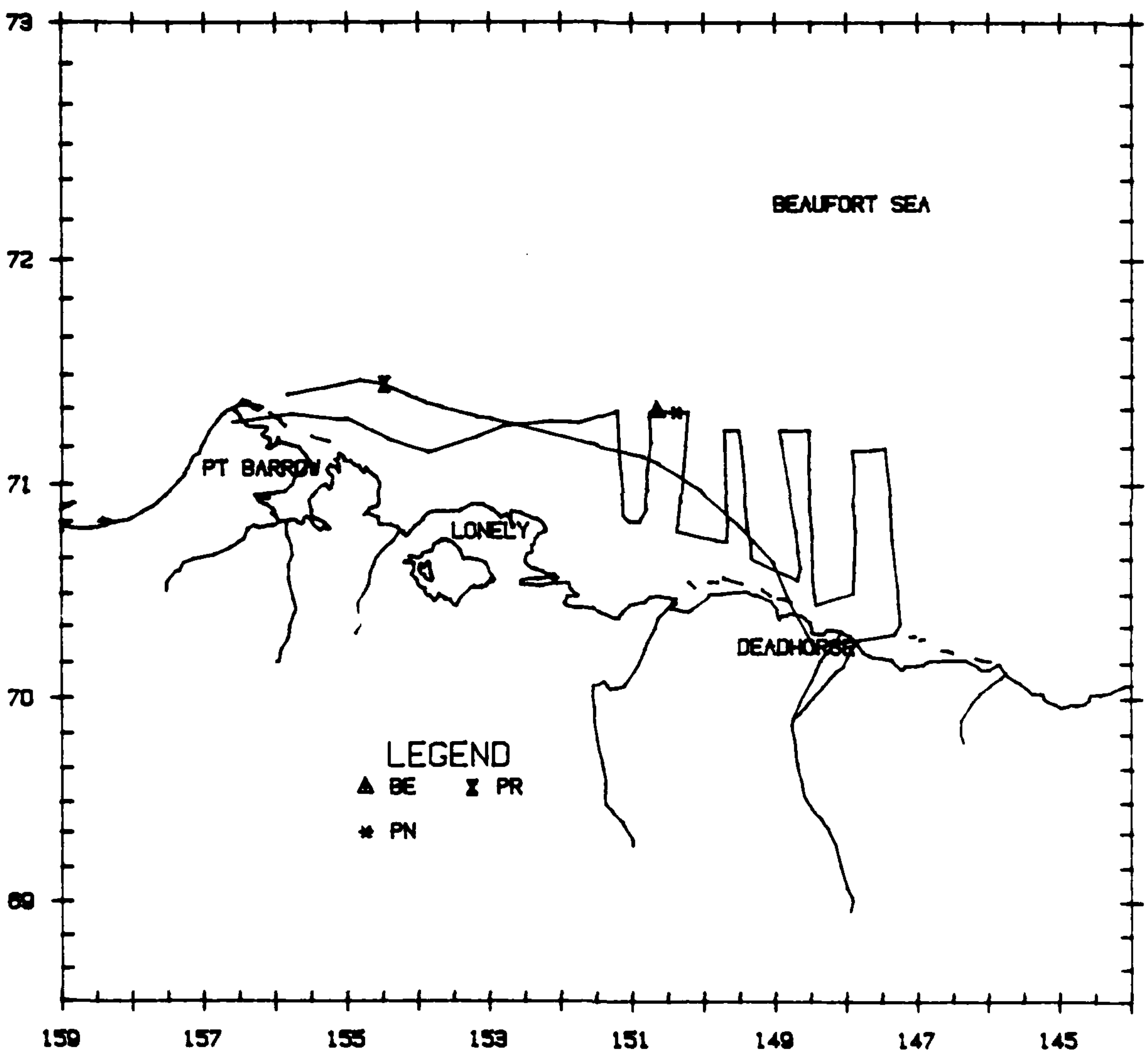
N780
Flight 53: 21 October 1986

Flight was a transect survey of the western one-half of block 17 and the easternmost line in block 18 with a search survey through blocks 15, 14, and 13. Weather was overcast with low ceilings (< 152 m) and visibility was 1 to 10 km. Ice cover was 90 to 99 percent in the northern one-third of block 17 and 0 to 10 percent in the remaining areas. Sea state was Beaufort 00 to 03. Two unidentified whales were seen, but could not be positively reidentified. Belukhas, walrus, and unidentified pinnipeds were also seen.


CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
BE
WS
CT
PN
73
72
71
70
69
165
163
161
159
157
155
153
151

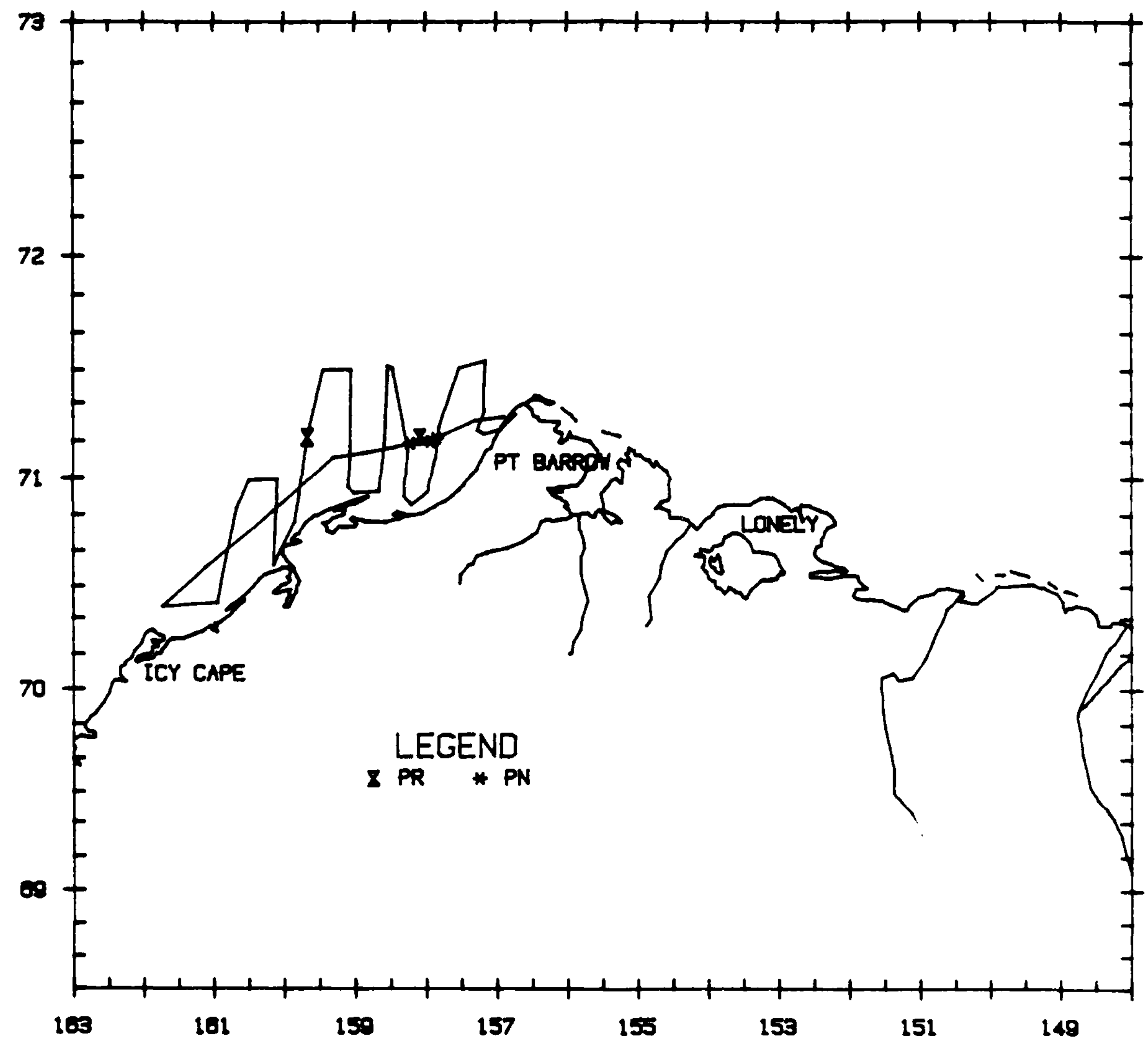
N780
Flight 54: 23 October 1986

Flight was a transect survey of portions of blocks 1, 2, and 3. Weather was clear with unlimited visibility over the ice, and fog, and numerous snow squalls with poor visibility (<2 km) over open-water areas. Ice varied from 0 to 99 percent in all areas. Sea state was Beaufort 00 to 01 in areas with heavy ice and Beaufort 03 to 05 in open-water areas. Belukhas, a polar bear, and an unidentified pinniped were seen.


BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
LEGEND
BE
PR
PN
73
72
71
70
69
159
157
155
153
151
149
147
145

N780
Flight 55: 24 October 1986

Flight was a transect survey of the southern one-half of block 13 and the eastern one-third of block 17. An attempted coastal search survey of block 17 and 20 was aborted due to high winds, high sea states (B05), and low visibility (< 1 km). Weather in block 13 was overcast, with visibility varying from 2 km to unlimited. Ice cover was 95 to 99 percent in the northern three-quarters of block 13 and northern one-quarter of block 17. Sea state was Beaufort 00 in heavy-ice areas and Beaufort 03 to 05 in open-water areas. Polar bears and unidentified pinnipeds were the only marine mammals seen.



73
72
71
70
69
163
161
159
157
155
153
151
149
PT BARROW
LONELY
ICY CAPE
LEGEND
PR
PN

APPENDIX B

OBSERVED DENSITIES OF BOWHEAD AND GRAY WHALES IN THE ALASKAN BEAUFORT AND EASTERN CHUKCHI SEAS, 1979-86

CONTENTS

Page

FIGURES

TABLES

INTRODUCTION

This appendix presents an analysis of endangered whales aerial survey data collected during 1986, and a summary of similarly analyzed data for 1979-85. The objectives of the analysis were to estimate the density of bowhead whales in the Beaufort Sea, and of gray whales in the Chukchi Sea. Estimating the density of a species provides an evaluation of the relative importance of an area to that group. The density estimate for a particular area is useful when assessing how a portion of a species' range is utilized by the population. Sequential density estimates provide an invaluable tool when determining a population's response to its environment through time.*

An important component of this analysis was determining the distribution of survey effort within specific areas. The Beaufort Sea was treated as the primary study area bounded by 141°W and 157°W longitude and 72°N latitude to the coastline. The Chukchi Sea was treated as a secondary study area bounded by 67°30'N and 72°N latitude and the coastline to 166°W longitude. Both study areas were subdivided to more precisely illustrate survey effort and density of animals. Distribution of survey effort and density of bowhead whales in the Beaufort Sea study area were examined during August, September, and October. Distribution of survey effort and density of bowhead and gray whales in the Chukchi Sea was examined during September and October.

METHODS

Density Estimates

Estimating population density requires calculating the portion of that population which is never sighted. In order to correctly estimate density of any population, four underlying assumptions must be adhered to. The assumptions are as follows:

- There are no measurement errors and no rounding errors.
- Sightings are independent events.
- Individuals are fixed at an initial sighting position and no individuals are counted twice.
- A sample of the population is collected at random; no individual is biasedly selected during a count (Cox, 1958; Anderson et al., 1976).

*Density estimates for 1986 endangered whales survey data were also calculated for survey blocks and provided in the report text (see Figures 12 and 16).

Two factors inherent in a study of cetaceans that cause an individual to be missed during a count are sightability and submergence. Sightability means an individual may be at the surface but missed by the observer. As the distance increases between the observer and a whale, the chance of sighting the whale decreases (Doi, 1974, 1975). Transect estimators are designed to work in planar situations. Hence, it is the portion of a population surfaced but not sighted that is calculated when estimating population density. Secondly, whales are not sighted because they are submerged. A distinction must be made between whales at the surface but not sighted, and submerged whales that cannot be sighted. Submerged whales are **never** calculated in the population density estimate. These whales represent a source of known but currently unmeasureable error in the total population estimate (Eberhardt et al., 1979). Additional assumptions peculiar to estimating cetacean density that stem from their sightability and submergence characteristics are:

- Only surfaced animals are counted, and density estimates are calculated only for the population of whales not submerged during an observation period.[1]
- The whales' behaviors do **not** change over the period for which an estimate is calculated (i.e., whales maintain the same swimming speeds and dive patterns throughout the migratory period). This assumption is critical, but difficult to satisfy because whales' behaviors do change over the period of migration.
- Observers are equally effective on both sides of the aircraft and in all areas of the sighting sector. This assumption is necessary since each observer's sightings are weighted equally by formulas used in calculating population size. Any deviation from this assumption will cause a negative or downward bias on the final estimate.

[1]A combined estimate of the population of surfaced and submerged whales can be calculated if a ratio of dive time to surface time is known. This ratio is a correction factor which permits one to adjust the population estimate to incorporate submerged whales. Presently no good correction factor exists for all behavioral situations. Bowheads seen during the fall in the Alaskan Beaufort Sea can either be actively migrating, moving slowly, resting, milling, or feeding. Although dive time ratios have been calculated for milling and feeding whales (see Table 41), these ratios are probably not appropriate to use as correction factors for migrating whales.

- Group size does not affect detection of whales. A violation of this assumption would cause a negative bias, since some classes of groups would not be sighted. This assumption is probably violated because larger groups are indeed easier to sight and because the larger the group, the higher the probability of having a whale at the surface.
- Whales do not evade the aircraft. This assumption is probably met because the speed of the aircraft is so much greater than that of the whales (i.e., the aircraft probably approaches a whale before the whale can evade it by diving).
- Unity of detection occurs on the flight track. All whales are sighted if they are on the transect line. The only whales that an observer fails to sight are those that are some distance away from the survey aircraft (Burnham et al., 1980).

Strip and Line Transect Methodologies. Strip transect and line transect represent two analytical methodologies used to derive density estimates. The fundamental difference between the two is that a strip transect samples a strip defined by boundaries, while line transect samples an area without boundaries. Both methods sample from a predetermined, randomly selected transect. The basic formula for strip transect estimators (Hayne, 1949) is:

$$N = \frac{nA}{2\,LH} \quad ,$$

where N is the estimated animal population, n is the number of individuals counted, A is area of strip, L is the transect length, and H is the mean sighting distance. Strip transects have a predetermined strip width, within which the observer is required to be certain of counting all individuals. This method does not utilize a detection function that incorporates sightings to the horizon. Individuals outside the strip are not counted, even if seen. For this reason, strip transect methods are recommended when the species density is high and individual counts are large. Line transect estimators are, conceptually, a strip transect with infinite strip width. Line transect methods use the following formula to estimate density:

$$D = \frac{n\,f(o)}{2L} \quad ,$$

where D is the estimated density, n is the number of animals sighted while surveying from a transect, f(o) is the normalized detection function or the probability of sighting an animal, and L is the total transect length surveyed. The number of animals sighted and the transect length surveyed are known parameters. The detection function is the probability of sighting a surfaced whale at a known distance from the transect and must be estimated for density to be calculated. It is used to determine the number of animals on the surface that are not seen. As long as sampling is completed as a series of random transects, the detection function f(o), is the critical estimation made. Determining which specific mathematical model best fits the detection function is most easily done by program computer models. TRANSECT (Burnham et al., 1980) is a program inclusive of parametric and nonparametric mathematical models applicable to fitting curves to data consisting of perpendicular distances.

A critical assumption that must be satisfied to validate the detection function is unity at the transect line; all individuals that occur on the transect line are counted. This assumption was violated because the aircraft's design prevented searching between clinometer angles of 90° and 70° from the horizon. To compensate, all perpendicular distances were adjusted by subtracting a distance from the transect's centerline to a parallel line drawn by the 70° angle specific for the highest altitude flown. The original assumption of unity is modified to assume unity of sightings at these two parallel lines (Figure B-1). The lines are placed at a position equidistant from the transect line, the distance being the perpendicular distance for a 70° clinometer angle at the highest altitude surveyed.

Previous studies have shown that both the accuracy and precision of line transect estimators rely on the ability of the observer to determine the exact distance of an individual sighting from the transect line. A fundamental problem now arises. The transect line has been transformed to represent two parallel lines determined by a 70° clinometer angle at the highest altitude surveyed. If a sighting occurs at an altitude lower than the altitude used to attain the parallel transect lines, but at a 70° angle, the sighting will occur in a mathematical "blind spot", the blind spot being the area between the two parallel lines. A blind spot confuses any effort to mathematically model the true probability of detecting whales at varying distances from the survey aircraft. A negative bias or underestimation of the true population is the result of a mathematical blind spot.

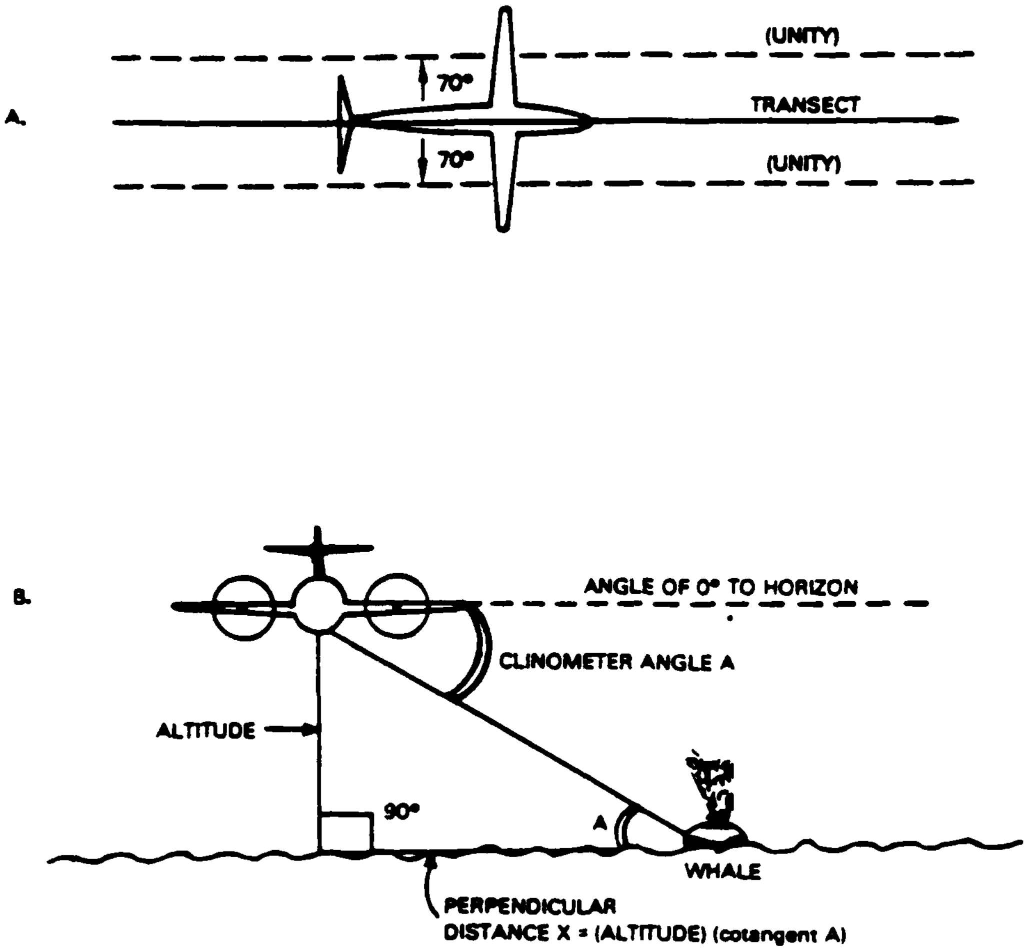


Figure B-1. Due to aircraft design, the assumption of unity at centerline is modified to assume unity at two parallel lines drawn by the 70° angle for the highest altitude flown.

A second method employed by Leatherwood et al. (in press) to compensate for the blind spot beneath the aircraft during line transect analysis, replaced the parallel-line assumption with a new one that requires all marine mammals to be seen at some fixed perpendicular distance (x_0) from the transect line. The resulting density values experience no aliasing, as introduced by the subtraction method when estimating sightability via the detection function, but nevertheless result in a minimum estimate.

One additional assumption that may be violated is that there are no measurement errors and no rounding errors. Exact sighting angles are difficult to obtain. A deviation of several degrees from the true sighting angle will significantly alter a line transect density estimate.

Map Preparation

Maps were prepared using the computer program AMP (A Mapping Package), consisting of FORTRAN subroutines which can be used for customized plotting applications. AMP was used to plot aerial survey data that resided on file as a series of geographic coordinates (latitude and longitude) associated with time and sightings of whales. Land masses are part of the AMP data base. Depth contours were plotted by reading a separate file of data points prepared for this analysis.

Depth contours were digitized using several reference maps. It was necessary to use more than one map because not all contours were available on any one map. The U.S. Geological Survey Map Open - File 76 - 823, Sheet 1 or 2 was used to digitize the 50-m and greater depth contours, plus all contours shown in the Chukchi Sea except for the 30-m depth contour off the Soviet coastline. The 30-m depth contour off the Soviet coastline and in the Bering Sea was taken from U.S. Department of Commerce map 514, 4th Ed., Apr. 11/81. In the Beaufort Sea, the 10-m, 20-m, and 30-m depth contours were taken from two maps labeled Data from: Geophysical Corp. of Alaska, 1975, NOAA, Department of Commerce Charts, USGS Department of Interior Charts, which were additionally labeled as Eastern Beaufort Sea and Western Beaufort Sea.

When the depth contours were merged onto a single data file and plotted, some inconsistencies became apparent. For example, a 30-m depth contour from one map file crossed over the 50-m depth contour from another map file. When this situation occurred, a portion of one of the depth contours was clipped to resolve the inconsistency. Note that portions of the 20-m and 30-m depth contours were clipped near Pt. Barrow, Alaska, and that the 50-m depth contour was clipped near St. Lawrence Island in the Bering Sea.

Data Processing and Quality Control

A computer program (SPEED).was written to screen for bad data values and to check the chronological order of time. Aerial survey data files were screened for obvious errors in geographic position by separately plotting the course of each daily aerial survey. A computer program was used to calculate flight speeds and distances on a point-to-point basis, and listings of these values were scanned for suspiciously slow or fast speeds. The listings and maps were compared; errors were flagged and edited and the process was repeated until data files were error-free with respect to these conditions.

Definition of Areas and Methodological Limitations

The Beaufort Sea study area was divided into four regions from west to east (Figure B-2). Region A extended from 157°00'W to 153°30'W, region B from 153°30'W to 150°00'W, region C from 150°00'W to 146°00'W, and region D from 146°00'W to 141°00'W. Depth contours (Figure B-3) were used to stratify the Beaufort Sea from north to south. Depth contours of 10 m, 20 m, 50 m, 200 m, and 200 m were selected (Figure B-4). The stratum from the coastline to 10 m corresponded closely to the area inside the barrier islands (A1, B1, C1, D1A, and D1B) (Figure B-5). Area D1 was divided into D1A and D1B at 143°30' W, which marked the boundary between two areas previously defined for behavioral studies (Figure B-6). The shelf area was stratified from 10 m to 20 m, 20 m to 50 m, and 50 m to 200 m. Areas A2, B2, C2, D2A and D2B corresponded to the 10-m to 20-m strata. Area D2 was divided similarly to D1. Areas A3, B3, C3, and D3 corresponded to the 20-m and 50-m strata. Areas A4, B4, C4, and D4 corresponded to the 50-m to 200-m strata. Offshelf strata were defined from 200 m to 2000 m and deeper than 2000 m. Areas A5, B5, C5, and D5 corresponded to the 200-m to 2000-m strata. Areas B6, C6, and D6 corresponded to the deeper than 2000-m strata.

Survey regions in the Chukchi Sea were determined based on survey effort and animal distributions (Figures B-7). Transect surveys have been conducted in the Chukchi Sea only since 1982. Prior to 1982, coastal search surveys were infrequently flown through the study area. The establishment of coastal (region 17) and offshore survey regions reflect this distribution of survey effort. These regions did not conform to survey blocks.

A digitizer was used to trace region boundaries, which led to a boundary problem termed "splinter error." The technique used to digitize each region was to circumscribe it by tracing the boundary of the region. Thus, when two regions were adjacent, the common boundary would be digitized twice. In fact, a boundary was often digitized more than twice. For example, the boundary between regions A1 and B1 was digitized four times because it served not only as a boundary between regions A1 and B1 but also between the larger regions A and B. A splinter error occurred when one set of points defining a common boundary did not exactly match the second, third, or fourth set of points used to define the same boundary for other regions.

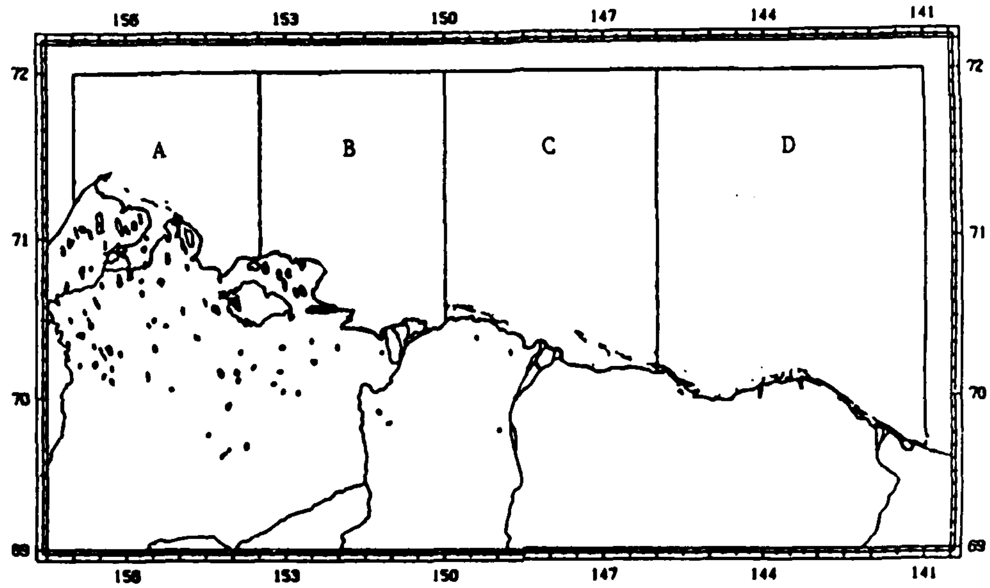


Figure B-2. The Beaufort Sea study area was divided into four regions: A, B, C, and D.

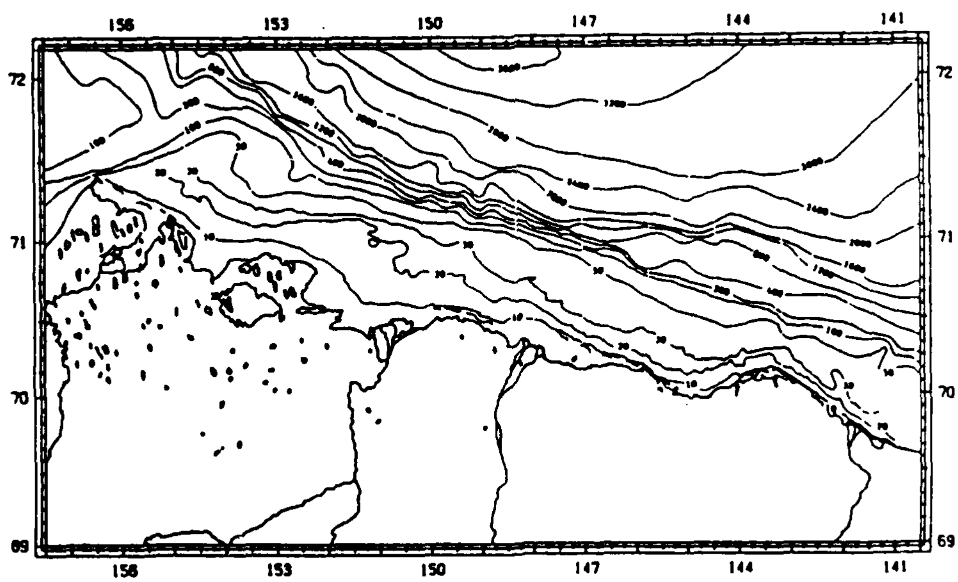


Figure B-3. Beaufort Sea depth contour lines, in meters.

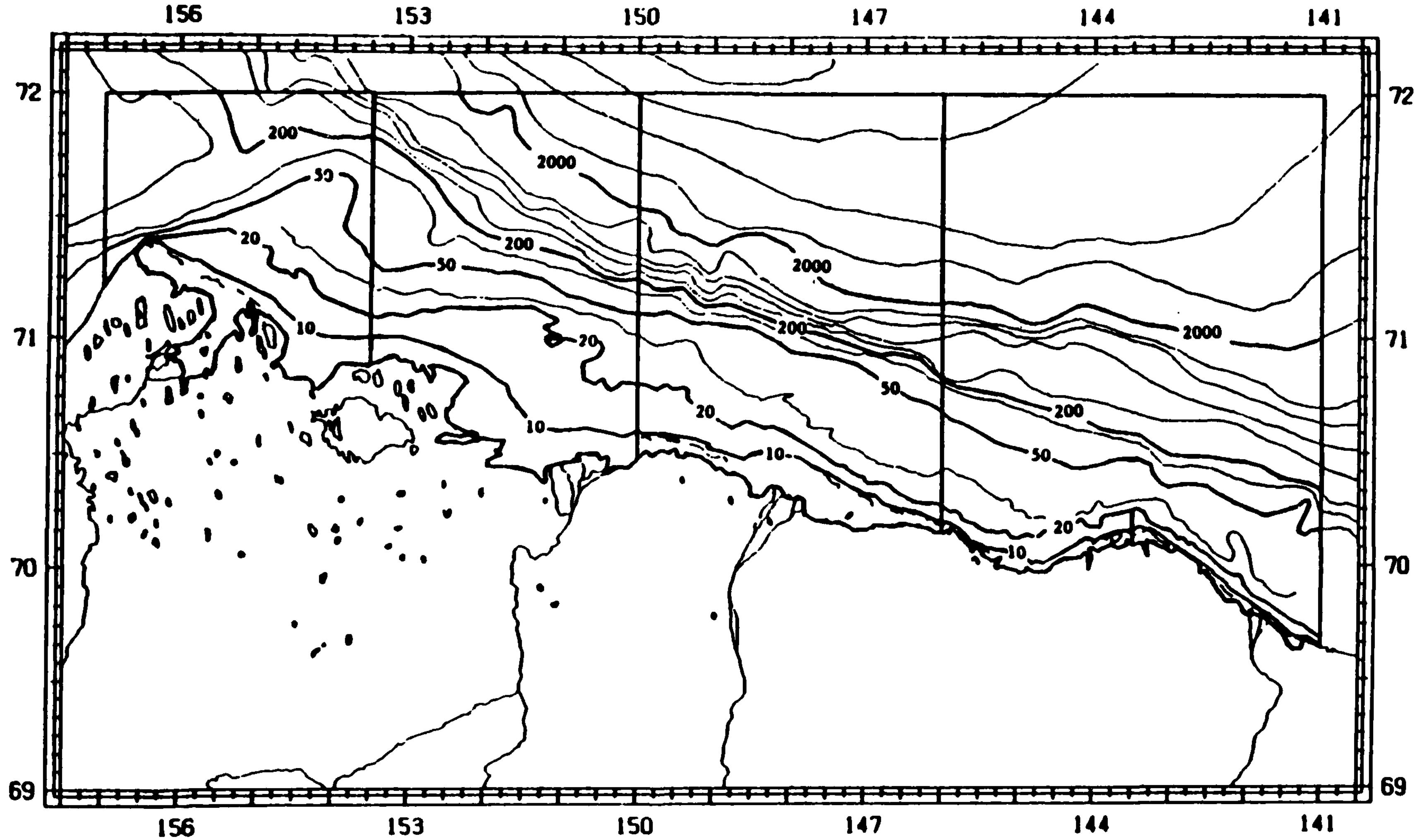


Figure B-4. Map depicting the survey regions in the Beaufort Sea after stratification by contour intervals of 10 m, 20 m, 50 m, 200 m and 2000 m.

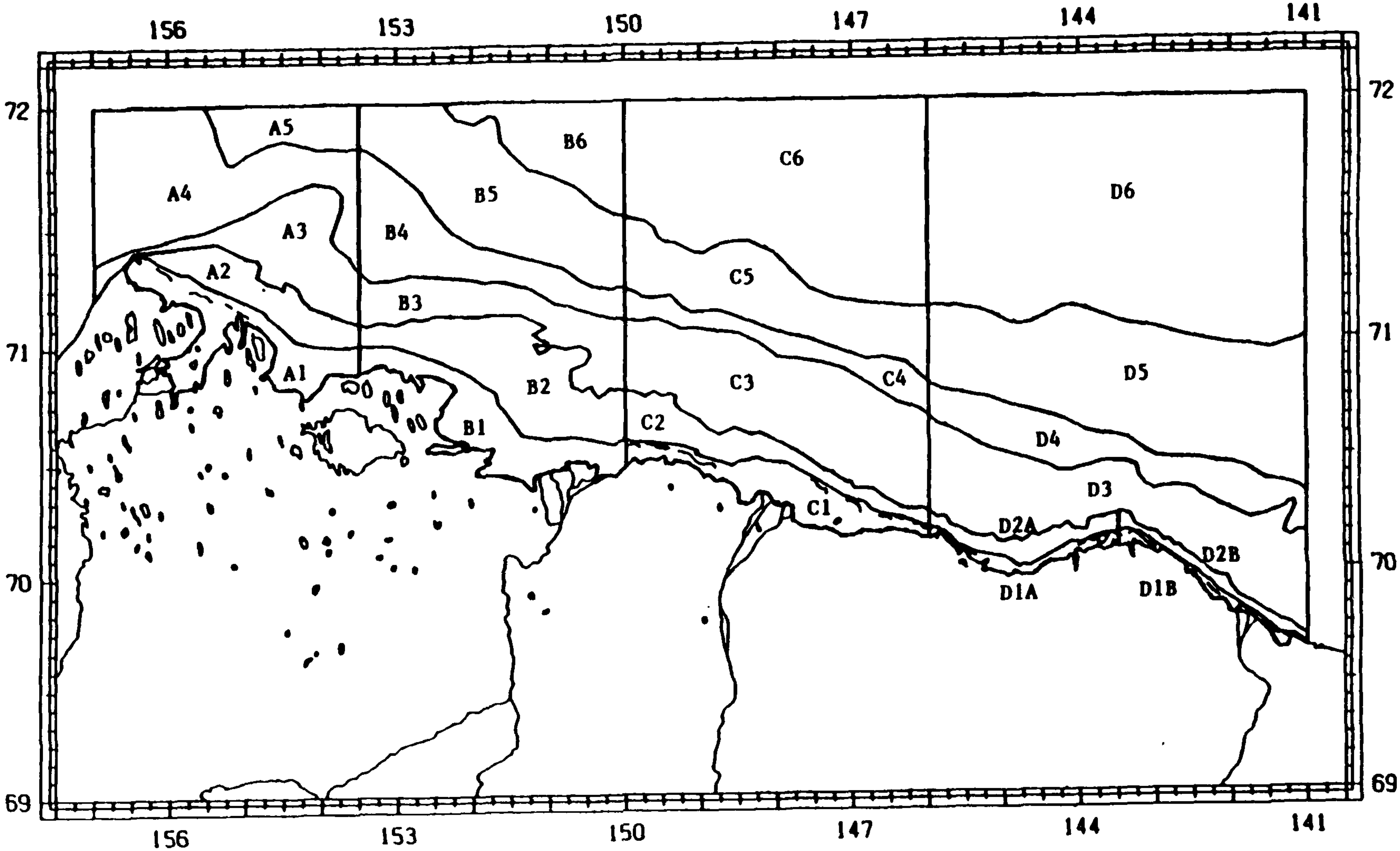


Figure B-5. Map depicting Beaufort Sea stratum names. Strata A1, B1, C1, D1A and D1B extended from the coast out to the 10 meter depth contour. Strata A2, B2, C2, D2A and D2B fell between the 10- and 20-meter depth contours; A3, B3, C3 and D3, fell between the 20- and 50-meter depth contours; etc. Strata D1A, D1B, D2A and D2B are enlarged in Figure B-6.

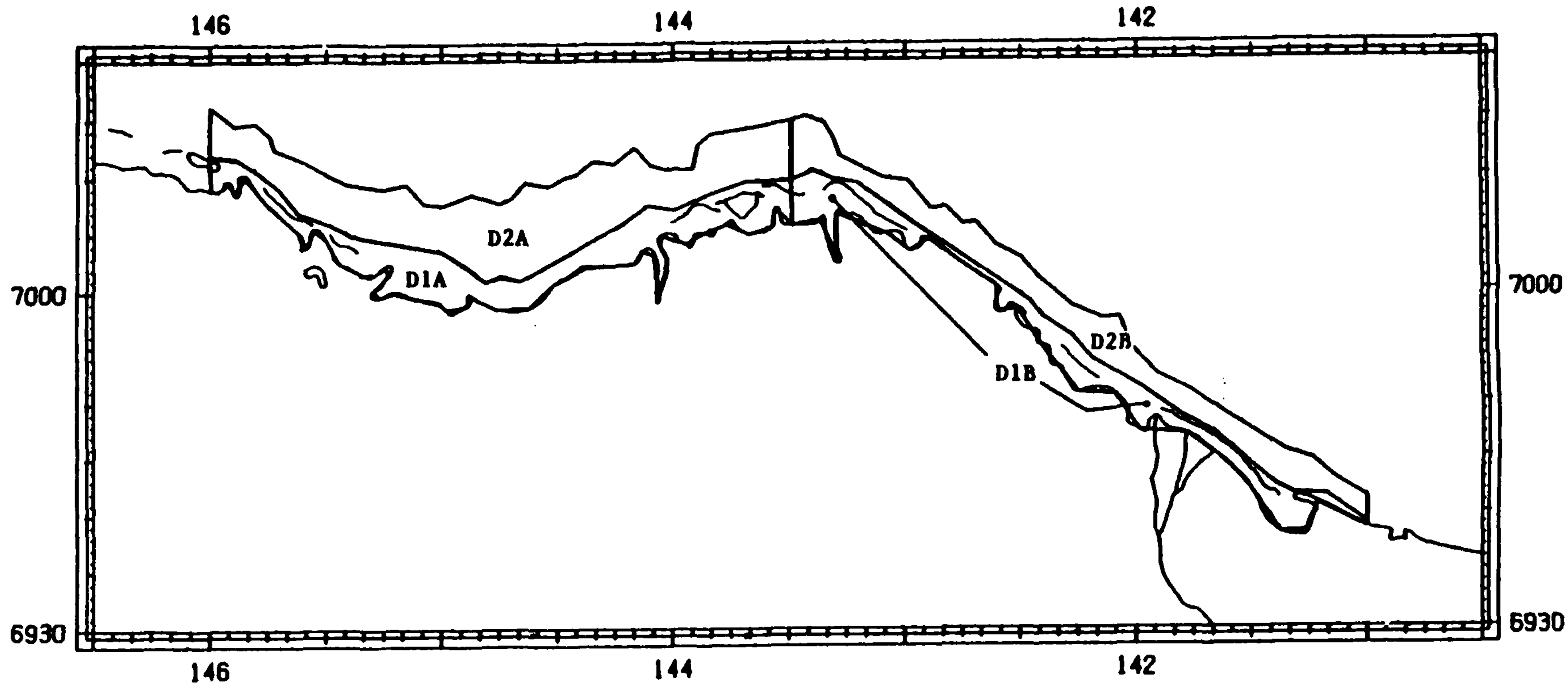


Figure B-6. Map depicting Beaufort Sea strata D1A, D1B, D2A and D2B. Regions D1A and D1B extended from the coast out to the 10-meter depth contour. Regions D2A and D2B extended from the 10-meter to the 20-meter depth contour.

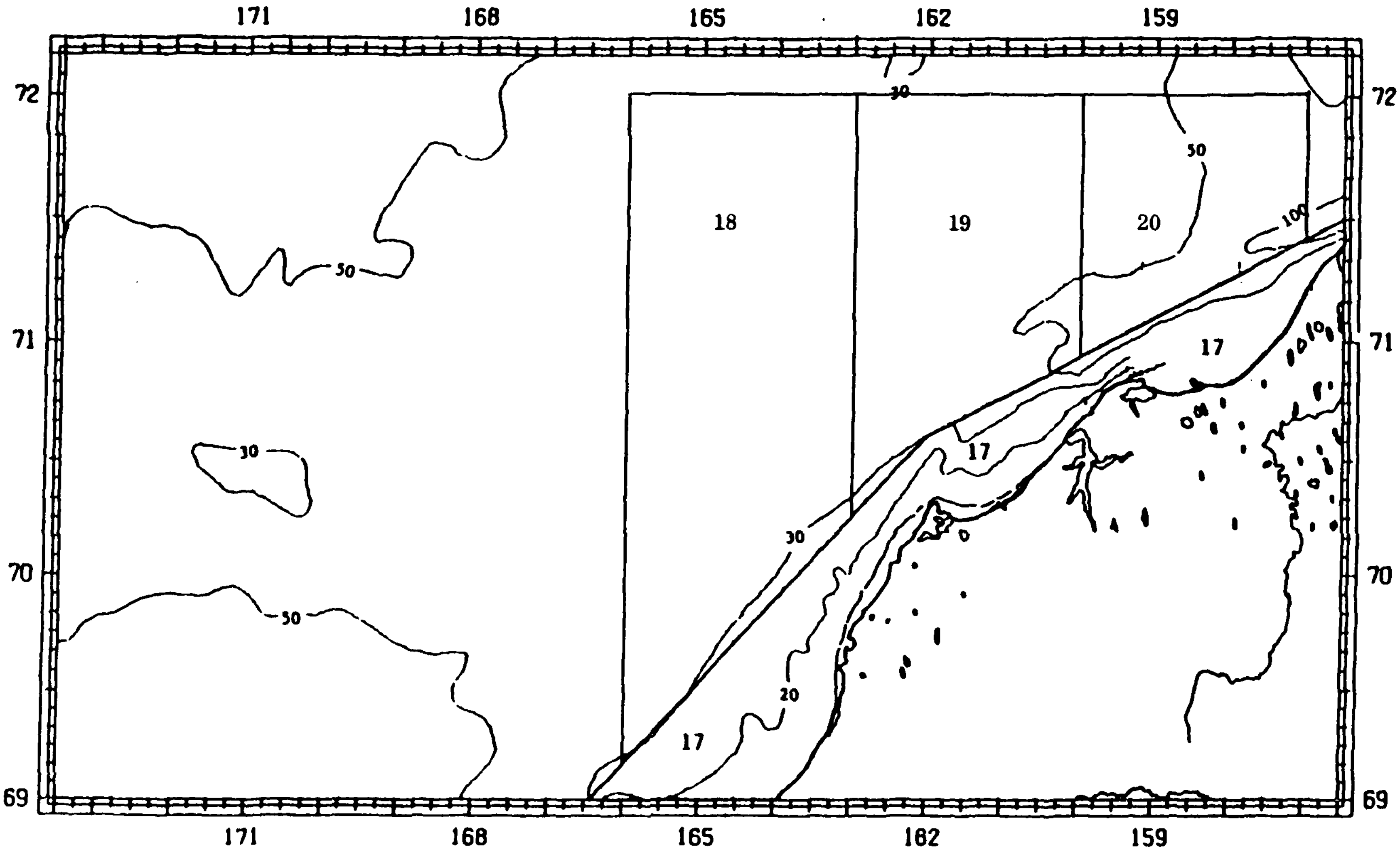


Figure B-7. Map depicting coastal survey region 17 and offshore regions 18, 19 and 20 in relation to depth contours in the Chukchi Sea.

Because of this splinter error problem, a very small percentage of the total area may be shared by two regions or may be left out of a region. For example, because of overlap, a small portion of the Beaufort Sea may have been shared during the analysis of two adjacent regions. Conversely, if two sets of points defining a common boundary diverged slightly, a small portion of the Beaufort Sea could have been left out of the analysis.

The implications of the splinter error problem are small in relation to this study. Statistics reported for each subregion, region, and the total study area are valid, but there may be small discrepancies when the values of subregions are summed and compared to the values reported for larger regions, e.g., number of survey hours flown, listed in the tables as survey time.

Statistics Presented in Tables

Region Area km^2. Areas were approximated by straight line integration which contributed to discrepancies between the summation of subregion areas and areas calculated for larger regions. Area calculations are accurate to within about 1 percent of the true area.

Percent of Total Area. The percent of total area was calculated as the region area divided by the sum of all subregion areas; this quantity was then multiplied by 100.

Percent of Area Surveyed. The percent of area surveyed is a relative measure of survey effort expended per survey region. Strip width was defined as two kilometers (i.e., one kilometer on either side of the aircraft). Therefore, the total number of kilometers flown equalled half the number of square kilometers surveyed. The percent of total area was calculated as the number of square kilometers surveyed divided by the region area; this quantity was then multiplied by 100.

This technique did not account for overlapping aerial survey strips which result in double counting the area surveyed. Therefore, some areas surveyed may show more than 100-percent coverage.

Survey Time HR:MIN. This is the time in hours and minutes spent surveying an area. Because of splinter errors and rounding errors, the values reported for time spent surveying subregions did not always equal those reported for larger regions.

Percent of Total Time. This is the time in hours and minutes spent surveying a region divided by the sum of survey times reported for each subregion.

Number of Transects Flown. Transects or flight legs were defined as units of survey effort by the aerial survey team. The beginning and ending of transects were further defined by the survey region boundaries. A portion of an aerial survey leg passing over a region was treated as a transect relative to that region. Thus, one transect could be broken into several transects with respect to subregion analyses. For this reason, the sum of the transects based on subregions was greater than the total number of transects reported for the total region.

Number of Bowheads Observed. This indicates the number of bowhead whales observed within one kilometer of either side of the aircraft.

Density as Number per km^2, Variance and Confidence Interval. Calculation of density statistics for each stratum followed the method employed by Krogman et al. (1979), which was based on the strip transect technique described in Estes and Gilbert (1978):

$$\hat{R} = \Sigma y_i / \Sigma x_i \qquad (1)$$

where $\hat{R}$ = observed density of whales per square kilometer

y_i = number of whales observed in the ith strip transect

x_i = area of the ith strip transect.

$$S^2_{\hat{R}} = [\Sigma(y_i^2/x_i) - R\Sigma y_i] / (n-1)(\Sigma x_i) \qquad (2)$$

where $S^2_{\hat{R}}$ = variance of R

n = number of strip transects.

$$C.I. = \hat{R} \pm t_{.05}(2)V\sqrt{V(\hat{R})} \qquad (3)$$

The notation $t_{0.05}(2)V$ refers to the critical value of t where alpha (α) - 0.05 (1- = 0.95) based on two-tailed test with V degrees of freedom. Degrees of freedom were calculated as the total number of transects minus one.

RESULTS

Results are presented by species, area, and month as outlined in the table of contents. Each presentation consists of a:

- Table of statistics associated with each region presenting 1986 data
- Summary table of statistics associated with each region, 1979-85

A histogram depicting subregional densities for combined 1979-86 bowhead data from the Alaskan Beaufort Sea is also presented.

Table B-1. Statistics from aerial surveys of bowhead whales conducted August 1986 in the Beaufort Sea. Values for each region were summed where appropriate. Region numbers refer to areas depicted in Figure B-5.

*The total area of all regions was approximately 101,248 km^2, as were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Bowheads Observed	Density as Number per 100 km^2	Variance (*10^{-4})	Confidence Range of Density
Total	*101,248	100.00	10.18	44:56	100.00	233	1	0.010	0.0001	0-0.030
A										
A1										
A2										
A3										
A4										
A5										
B										
B1										
B2										
B3										
B4										
B5										
B6										
C										
C1										
C2										
C3										
C4										
C5										
C6										
D	41,139	40.63	25.06	44:56	100.00	233	1	0.010	0.0001	0-0.030
D1A	494	0.49	17.28	0:11	0.42	12	0	0	0	0
D1B	428	0.42	4.41	0:03	0.10	7	0	0	0	0
D2A	915	0.90	50.65	0:56	2.09	27	0	0	0	0
D2B	510	0.50	33.15	0:21	0.79	15	0	0	0	0
D3	6,933	6.85	47.19	6:36	14.68	53	0	0	0	0
D4	3,462	3.42	38.57	2:42	6.02	53	0	0	0	0
D5	9,785	9.66	27.89	28:55	64.35	40	1	0.037	0.0023	0-0.133
D6	18,612	18.38	12.02	5:12	11.55	26	0	0	0	0

Table B-2. Statistics from aerial surveys of bowhead whales conducted August 1979-85 in the Alaskan Beaufort Sea.

		1979			1980			1981		
Region Name	Region Area km²	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km²
Total	101,248	8.84	4	0.045	4.23	0	0.0	0.0		
A	13,360	0.0			1.46	0	0.0	0.0		
A1	2,361	0.0			1.27	0	0.0	0.0		
A2	1,648	0.0			3.62	0	0.0	0.0		
A3	2,688	0.0			3.76	0	0.0	0.0		
A4	5,166	0.0			0.08	0	0.0	0.0		
A5	1,497	0.0			0.0					
B	19,393	0.0			11.07	0	0.0	0.0		
B1	2,614	0.0			12.44	0	0.0	0.0		
B2	3,814	0.0			25.49	0	0.0	0.0		
B3	2,739	0.0			21.42	0	0.0	0.0		
B4	3,061	0.0			8.38	0	0.0	0.0		
B5	5,009	0.0			0.38	0	0.0	0.0		
B6	2,336	0.0			0.0			0.0		
C	27,156	17.33	0	0.0	7.07	0	0.0	0.0		
C1	2,086	36.43	0	0.0	11.92	0	0.0	0.0		
C2	1,809	33.33	0	0.0	20.21	0	0.0	0.0		
C3	6,482	34.80	0	0.0	18.91	0	0.0	0.0		
C4	1,803	3.93	0	0.0	4.22	0	0.0	0.0		
C5	4,252	5.01	0	0.0	0.12	0	0.0	0.0		
C6	10,724	0.22	0	0.0	0.0			0.0		
D	41,139	10.33	4	0.094	0.0			0.0		
D1A	496	[illegible].50	0	0.0	0.0			0.0		
D1B	428	0.0			0.0			0.0		
D2A	913	34.04	0	0.0	0.0			0.0		
D2B	510	3.58	0	0.0	0.0			0.0		
D3	6,933	39.20	0	0.0	0.0			0.0		
D4	3,462	22.27	[illegible]	0.130	0.0			0.0		
D5	9,785	4.30	3	0.716	0.0			0.0		
D6	18,612	0.0			0.0			0.0		

		1982			1983			1984			1985		
Region Name	Region Area km²	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km²
Total	[illegible]248	8.92	45	0.235	19.00	0	0.0	[illegible]33	1	0.026	[illegible]		0.008
A	[illegible]360	0.0			[illegible]61	0	0.0	[illegible]22	0	0.0			
A1	[illegible]	0.0			[illegible]84	0	0.0	[illegible]63	0	0.0			
A2	[illegible]648	0.0			26.[illegible]	0	0.0	[illegible]87	0	0.0			
A3	[illegible]688	0.0			[illegible]35	0	0.0	[illegible]	0	0.0			
A4	[illegible]166	0.0			4.94	0	0.0	[illegible]88	0	0.0			
A5	[illegible]497	0.0			8.43	0	0.0	2.82	0	0.0			
B	[illegible]	0.0			8.90	0	0.0	[illegible]	[illegible]	0.0			
B1	[illegible]	0.0			[illegible]	0	0.0	[illegible]35	[illegible]	0.0			
B2	[illegible]	0.0			32.[illegible]	0	0.0	[illegible]26	[illegible]	[illegible]			
B3	[illegible]	0.0			28.55	0	[illegible]	[illegible]30	[illegible]	[illegible]			
B4	[illegible]	0.0			[illegible]43	0	[illegible]	[illegible]	[illegible]	[illegible]			
B5	[illegible]009	0.0			0.68	0	[illegible]	[illegible]35	[illegible]	[illegible]			
B6	[illegible]	0.0			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
C	[illegible]	2.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
C1	[illegible]	[illegible]69	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
C2	[illegible]809	[illegible]97	[illegible]	[illegible]	[illegible]62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
C3	[illegible]482	9.63	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
C4	[illegible]803	22.36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
C5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
C6	[illegible]724	[illegible]89	[illegible]	[illegible]	20.64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
D	[illegible]	18.[illegible]	45	[illegible].284	23.[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible].026	[illegible]		
D1A	[illegible]	[illegible]28	[illegible]	[illegible]	[illegible]46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
D1B	[illegible]428	[illegible]	[illegible]	[illegible]	[illegible]94	[illegible]	[illegible]	[illegible]44	[illegible]	[illegible]	[illegible]		
D2A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]96	[illegible]	[illegible]	[illegible]		
D2B	[illegible]	[illegible]	[illegible]	[illegible]	20.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
D3	[illegible]	[illegible]	[illegible]	[illegible]	9.64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
D4	[illegible]462	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			
D5	[illegible]	[illegible]	18	[illegible]	[illegible]			[illegible]			[illegible]		
D6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]98			[illegible]			[illegible]		

Table B-3. Statistics from aerial surveys of bowhead whales conducted September 1986 in the Beaufort Sea. Values for each region were summed where appropriate. Region numbers refer to areas depicted in Figure B-5.

* The total area of all regions was approximately 101,248 km^2; areas were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Bowheads Observed	Density as Number per 100 km^2	Variance ($*10^{-4}$)	Confidence Range of Density
Total	*101,248	100.00	23.41	50:44	100.00	564	16	0.067	0.0004	0.024-0.111
A	13,360	13.20	10.26	2:44	5.39	32	0	0	0	0
A1	2,361	2.33	2.14	0:06	0.21	4	0	0	0	0
A2	1,648	1.63	10.94	0:22	0.73	6	0	0	0	0
A3	2,688	2.65	11.28	0:36	1.19	9	0	0	0	0
A4	5,166	5.10	12.98	1:20	2.62	9	0	0	0	0
A5	1,497	1.48	11.13	0:20	0.64	4	0	0	0	0
B	19,593	19.35	9.65	4:08	8.16	52	0	0	0	0
B1	2,614	2.58	5.57	0:20	0.66	8	0	0	0	0
B2	3,814	3.77	15.87	1:20	2.63	13	0	0	0	0
B3	2,739	2.71	13.24	0:48	1.57	11	0	0	0	0
B4	3,061	3.02	12.60	0:48	1.59	12	0	0	0	0
B5	5,009	4.95	7.27	0:49	1.61	6	0	0	0	0
B6	2,357	2.33	1.18	0:03	0.11	2	0	0	0	0
C	27,156	26.82	25.70	14:51	29.28	178	0	0	0	0
C1	2,086	2.06	11.65	0:36	1.20	22	0	0	0	0
C2	1,809	1.79	44.12	1:47	3.51	39	0	0	0	0
C3	6,482	6.40	53.43	7:17	14.36	49	0	0	0	0
C4	1,803	1.78	35.72	1:22	2.70	28	0	0	0	0
C5	4,252	4.20	23.29	2:00	3.93	26	0	0	0	0
C6	10,724	10.59	7.83	1:49	3.57	14	0	0	0	0
D	41,139	40.63	32.73	29:00	57.17	302	16	0.119	0.0016	0.040-0.197
D1A	494	0.49	10.33	0:07	0.22	12	0	0	0	0
D1B	428	0.42	11.46	0:06	0.21	9	0	0	0	0
D2A	915	0.90	63.01	1:14	2.43	33	0	0	0	0
D2B	510	0.50	30.18	0:21	0.68	18	1	0.650	0.5468	0-2.21
D3	6,933	6.85	61.14	9:11	18.10	69	14	0.330	0.0155	0.082-0.578
D4	3,462	3.42	41.62	3:07	6.14	62	1	0.069	0.0026	0-0.171
D5	9,785	9.66	43.52	9:10	18.07	56	0	0	0	0
D6	18,612	18.38	14.49	5:44	11.31	43	0	0	0	0

Table B-4. Statistics from aerial surveys of bowhead whales conducted September 1979-85 in the Beaufort Sea.

		1979			1980			1981		
Region Name	Region Area km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km^2
Total	101,248	10.17	0	0.0	13.19	3	0.022	3.96	1	0.025
A	13,360	0.0			2.67	0	0.0	1.22	0	0.0
A1	2,361	0.0			2.23	0	0.0	0.70	0	0.0
A2	1,648	0.0			6.71	0	0.0	3.35	0	0.0
A3	2,688	0.0			7.06	0	0.0	3.38	0	0.0
A4	5,166	0.0			0.06	0	0.0	0.0		
A5	1,497	0.0			0.0			0.0		
B	19,593	0.0			18.20	0	0.0	5.75	0	0.0
B1	2,614	0.0			10.40	0	0.0	2.48	0	0.0
B2	3,814	0.0			41.11	0	0.0	11.81	0	0.0
B3	2,739	0.0			44.40	0	0.0	15.74	0	0.0
B4	3,061	0.0			14.20	0	0.0	4.86	0	0.0
B5	5,009	0.0			1.51	0	0.0	0.62	0	0.0
B6	2,356	0.0			0.0			0.0		
C	27,156	23.14	0	0.0	34.75	3	0.032	9.74	1	0.038
C1	2,086	57.24	0	0.0	65.84	0	0.0	18.14	0	0.0
C2	1,809	63.44	0	0.0	111.55	0	0.0	29.30	0	0.0
C3	6,482	48.47	0	0.0	89.45	3	0.052	26.01	1	0.059
C4	1,803	18.06	0	0.0	13.66	0	0.0	2.70	0	0.0
C5	4,252	9.46	0	0.0	0.0	0	0.0	0.04	0	0.0
C6	10,724	0.68	0	0.0	0.0			0.0		
D	41,139	9.76	0	0.0	0.0			0.18	0	0.0
D1A	494	1.44	0	0.0	0.0			1.08	0	0.0
D1B	628	0.0			0.0			0.0		
D2A	915	40.89	0	0.0	0.0			2.77	0	0.0
D2B	510	1.82	0	0.0	0.0			0.0		
D3	6,933	35.75	0	0.0	0.0			0.63	0	0.0
D4	3,462	27.38	0	0.0	0.0			0.0		
D5	9,785	2.02	0	0.0	0.0			0.0		
D6	18.612	0.0			0.0			0.0		

		1982			1983			1984			1985		
Region Name	Region Area km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per 100 km^2
Total	101,248	19.96	26	0.13	32.10	24	0.07	18.13	14	0.08	14.30	0	0
A	13,360	13.85	2	0.11	32.20	5	0.12	10.45	3	0.22	8.68	0	0
A1	2,361	8.00	0	0.0	8.79	0	0.0	3.41	0	0.0	2.61	0	0
A2	1,648	24.03	0	0.0	36.17	0	0.0	12.94	0	0.0	10.71	0	0
A3	2,688	25.53	0	0.0	43.55	2	0.17	11.81	1	0.32	10.31	0	0
A4	5,166	10.39	2	0.37	34.45	3	0.17	11.98	2	0.32	10.05	0	0
A5	1,497	2.78	0	0.0	36.59	0	0.0	11.09	0	0.0	8.31	0	0
B	19,593	33.17	3	0.05	47.10	7	0.08	18.20	0	0.0	5.58	0	0
B1	2,614	23.33	0	0.0	20.86	0	0.0	9.69	0	0.0	6.02	0	0
B2	3,814	51.44	1	0.05	42.70	0	0.0	30.90	0	0.0	13.29	0	0
B3	2,739	58.88	2	0.12	50.58	3	0.22	32.33	0	0.0	11.99	0	0
B4	3,061	39.09	0	0.0	61.98	2	0.10	16.34	0	0.0	3.32	0	0
B5	5,009	18.58	0	0.0	53.83	1	0.04	11.19	0	0.0	0.0		
B6	2,356	7.94	0	0.0	45.63	1	0.09	7.94	0	0.0	0.0		
C	27,156	13.06	17	0.48	40.42	6	0.06	23.90	4	0.06	15.73	0	0
C1	2,086	25.73	0	0.0	20.58	0	0.0	18.52	0	0.0	9.68	0	0
C2	1,809	34.47	1	0.16	32.99	0	0.0	31.18	0	0.0	28.73	0	0
C3	6,482	29.47	16	0.84	38.00	0	0.0	34.22	[illegible]	0.05	30.43	0	[illegible]
C4	1,803	13.46	0	0.0	48.99	0	0.0	21.68	3	0.77	24.45	0	[illegible]
C5	4,252	5.41	0	0.0	30.61	4	0.19	20.36	0	0.0	21.29	0	0
C6	10,724	0.02	0	0.0	41.52	2	0.04	19.27	0	0.0	[illegible]	0	0
D	41,139	20.21	4	0.05	19.42	6	0.08	16.79	[illegible]	0.10	19.34	[illegible]	0
D1A	494	5.04	0	0.0	4.32	0	0.0	8.33	0	0.0	[illegible]	0	[illegible]
D1B	628	11.46	0	0.0	1.57	0	0.0	4.99	0	0.0	[illegible]	[illegible]	0
D2A	915	30.13	0	0.0	18.73	0	0.0	18.62	0	0.0	24.99	0	0
D2B	510	27.33	0	0.0	19.41	0	0.0	41.10	0	0.0	22.15	0	0
D3	6,933	35.45	0	0.0	19.11	0	0.0	27.79	6	0.31	30.92	0	0
D4	3,462	33.01	0	0.0	34.84	2	0.17	18.93	0	0.0	25.25	0	
D5	9,785	20.92	0	0.0	29.81	4	0.14	16.33		0.06	[illegible]	[illegible]	
D6	18,612	11.70	4	0.18	12.05	0	0.0	12.27	0	0.0	[illegible]	[illegible]	

Table B-5. Statistics from aerial surveys of bowhead whales conducted October 1986 in the Beaufort Sea. Values for each region were summed where appropriate. Region numbers refer to areas depicted in Figure B-5.

*The total area of all regions was approximately 101,248 km^2; areas were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Bowheads Observed	Density as Number per 100 km^2	Variance (*10^{-4})	Confidence Range of Density
Total	*101,248	100.00	14.13	30:35	100.00	370	12	0.084	0.0009	0.022-0.146
A	13,360	13.20	26.47	7:25	24.25	77	4	0.113	0.0034	0-0.230
A1	2,361	2.33	6.04	0:18	0.96	12	0	0	0	0
A2	1,648	1.63	29.90	1:03	3.45	14	1	0.203	0.0517	0-0.694
A3	2,688	2.65	28.68	1:38	5.34	19	3	0.389	0.0359	0-0.787
A4	5,166	5.10	34.02	3:41	12.07	22	0	0	0	0
A5	1,497	1.48	24.85	0:45	2.43	10	0	0	0	0
B	19,593	19.35	16.40	6:55	22.64	88	0	0	0	0
B1	2,614	2.58	7.78	0:27	1.46	12	0	0	0	0
B2	3,814	3.77	22.76	1:55	6.27	19	0	0	0	0
B3	2,739	2.71	24.32	1:27	4.75	20	0	0	0	0
B4	3,061	3.02	20.15	1:20	4.35	21	0	0	0	0
B5	5,009	4.95	11.70	1:14	4.02	11	0	0	0	0
B6	2,356	2.33	11.60	0:33	1.79	5	0	0	0	0
C	27,156	26.82	21.83	12:44	41.64	167	8	0.135	0.0043	0.005-0.265
C1	2,086	2.06	11.36	0:31	1.67	21	0	0	0	0
C2	1,809	1.79	47.17	1:50	6.00	38	6	0.703	0.0997	0.064-1.343
C3	6,482	6.40	46.07	6:23	20.86	44	0	0	0	0
C4	1,803	1.78	36.16	1:25	4.64	30	0	0	0	0
C5	4,252	4.20	24.51	2:14	7.28	27	2	0.192	0.0280	0-0.536
C6	10,724	10.59	1.48	0:22	1.19	7	0	0	0	0
D	41,139	40.63	3.96	3:30	11.47	38	0	0	0	0
D1A	494	0.49	0.0	0:00	0.0	0	0	0	0	0
D1B	428	0.42	1.93	0:01	0.07	1	0	0	0	0
D2A	915	0.90	9.24	0:01	0.52	6	0	0	0	0
D2B	510	0.50	1.00	0:01	0.04	1	0	0	0	0
D3	6,933	6.85	9.47	1:23	4.53	10	0	0	0	0
D4	3,462	3.42	9.59	0:42	2.26	10	0	0	0	0
D5	9,785	9.66	4.93	1:06	3.59	6	0	0	0	0
D6	18,612	18.38	0.33	0:08	0.46	4	0	0	0	0

Table B-6. Statistics from aerial surveys of bowhead whales conducted October 1979-85 in the Beaufort Sea.

Region Name	Region Area km²	1979 Percent of Area Surveyed	1979 Number Bowheads Observed	1979 Density as Number per 100 km²	1980 Percent of Area Surveyed	1980 Number Bowheads Observed	1980 Density as Number per 100 km²	1981 Percent of Area Surveyed	1981 Number Bowheads Observed	1981 Density as Number per 100 km²
Total	101,284	12.64	20	0.156	10.97	3	0.036	10.11	7	0.068
A	13,360	7.69	0	0.0	3.46	0	0.0	1.44	0	0.0
A1	2,361	0.0	0	0.0	5.79	0	0.0	1.30	0	0.0
A2	1,648	1.40	0	0.0	15.66	0	0.0	4.04	0	0.0
A3	2,688	8.44	0	0.0	12.39	0	0.0	3.38	0	0.0
A4	5,166	12.87	0	0.0	0.04	0	0.0	0.0		
A5	1,497	7.46	0	0.0	0.0			0.0		
B	19,993	4.25	7	0.841	29.35	1	0.017	18.27	3	0.084
B1	2,614	0.0	0	0.0	23.45	0	0.0	10.16	0	0.0
B2	3,814	3.46	0	0.0	63.35	0	0.0	43.03	0	0.0
B3	2,739	13.47	7	1.898	68.25	1	0.053	41.78	3	0.262
B4	3,061	6.94	0	0.0	20.33	0	0.0	14.00	0	0.0
B5	5,009	2.39	0	0.0	2.77	0	0.0	2.00	0	0.0
B6	2,356	0.0			0.0			0.0		
C	27,156	33.32	11	0.122	17.04	2	0.043	13.74	3	0.080
C1	2,086	84.42	0	0.0	27.43	0	0.0	18.73	0	0.0
C2	1,809	83.60	0	0.0	46.41	0	0.0	37.54	1	0.147
C3	6,482	69.38	11	0.245	47.74	2	0.065	38.10	2	0.081
C4	1,803	24.67	0	0.0	6.62	0	0.0	10.62	0	0.0
C5	4,252	17.12	0	0.0	0.02	0	0.0	0.0		
C6	10,724	0.99	0	0.0	0.00	0	0.0	0.0		
D	41,139	4.39	2	0.106	0.0			6.63	1	0.037
D1A	494	0.67	0	0.0	0.0			0.45	0	0.0
D1B	428	0.0			0.0			0.17	0	0.0
D2A	915	21.60	0	0.0	0.0			14.79	0	0.0
D2B	310	0.0			0.0			4.44	0	0.0
D3	6,933	19.95	2	0.145	0.0			15.83	1	0.091
D4	3,462	6.31	0	0.0	0.0			14.13	0	0.0
D5	9,785	0.86	0	0.0	0.0			9.82	0	0.0
D6	18,612	0.02	0	0.0	0.0			0.15	0	0.0

Region Name	Region Area km²	1982 Percent of Area Surveyed	1982 Number Bowheads Observed	1982 Density as Number per 100 km²	1983 Percent of Area Surveyed	1983 Number Bowheads Observed	1983 Density as Number per 100 km²	1984 Percent of Area Surveyed	1984 Number Bowheads Observed	1984 Density as Number per 100 km²	1985 Percent of Area Surveyed	1985 Number Bowheads Observed	1985 Density as Number per 100 km²
Total	101,298	9.33	14	0.148	12.58	7	0.055	18.82	27	0.14	16.58	[illegible]	0.068
A	13,360	24.09	5	0.155	32.88	4	0.091	35.51	19	0.40	32.69	[illegible]	0.092
A1	2,361	6.72	0	0.0	6.16	0	0.0	4.83	0	0.0	10.32	[illegible]	0.0
A2	1,648	21.70	2	0.559	34.35	0	0.0	44.63	6	0.82	44.10		[illegible]
A3	2,688	27.26	1	[illegible] 136	35.40	3	0.315	38.45	5	0.48	41.84	[illegible]	[illegible]
A4	5,166	31.53	2	0.123	42.92	1	0.045	44.39	8	0.35	35.64	[illegible]	[illegible]
A5	1,497	22.79	0	0.0	34.20	0	0.0	37.94	0	0.0	[illegible]	[illegible]	[illegible]
B	19,993	14.41	8	0.283	19.74	3	0.078	37.23	7	0.10	[illegible]	[illegible]	[illegible]
B1	2,614	2.75	0	0.0	6.04	0	0.0	24.82	0	0.0	18.90	[illegible]	[illegible]
B2	3,814	[illegible].55	0	0.0	20.92	0	0.0	67.79	1	0.04	38.95	[illegible]	[illegible]
B3	2,739	10.63	7	2.405	22.24	3	0.492	69.49	2	0.10	[illegible]		[illegible]
B4	3,361	19.59	0	0.0	21.91	0	0.0	41.02	4	0.32	[illegible]	[illegible]	[illegible]
B5	5,309	23.67	1	0.084	22.59	0	0.0	16.26	0	0.0	[illegible]	[illegible]	[illegible]
B6	2,356	17.[illegible]	0	0.0	21.65	0	0.0	5.70	0	0.0	[illegible]	[illegible]	[illegible]
C	27,[illegible]56	6.32	1	0.058	[illegible].57	0	0.0	20.26	1	0.02	8.96	[illegible]	[illegible]
C1	2,086	10.23	0	0.0	8.66	0	0.0	19.33	0	0.0	[illegible]		[illegible]
C2	1,809	16.31	0	0.0	10.64	0	0.0	40.65	0	0.0	17.30	[illegible]	[illegible]
C3	6,482	17.27	1	0.089	10.75	0	0.0	43.79	1	0.04	21.93	[illegible]	[illegible]
C4	1,803	3.94	0	0.0	10.49	0	0.0	33.80	0	0.0	[illegible].22	[illegible]	[illegible]
C5	4,252	0.59	0	0.0	10.60	0	0.0	18.54	0	0.0	[illegible]	[illegible]	[illegible]
C6	10,724	0.0			3.22	0	0.0	1.16	0	0.0	[illegible]	[illegible]	[illegible]
D	41,139	4.09	0	0.0	3.89	0	0.0	3.69	0	0.0	[illegible]	[illegible]	[illegible]
D1A	494	5.21	0	0.0	9.28	0	0.0	1.12	0	0.0	[illegible]	[illegible]	[illegible]
D1B	428	3.44	0	0.0	3.44	0	0.0	0.09	0	0.0	[illegible]	[illegible]	[illegible]
D2A	915	22.34	0	0.0	15.23	0	0.0	9.27	0	0.0	[illegible]		[illegible]
D2B	310	11.20	0	0.0	4.87	0	0.0	6.21	0	0.0	[illegible]		
D3	6,933	[illegible]	0	0.0	10.80	0	0.0	9.90	0	0.0	[illegible]		[illegible]
D4	3,462	5.75	0	0.0	12.37	0	0.0	7.80	0	0.0	[illegible]	[illegible]	[illegible]
D5	9,785	3.94	0	0.0	9.97	0	0.0	4.67	0	0.0	[illegible]		
D6	18,612	0.01	0	0.0	3.31	0	0.0	3.00	0	0.0	[illegible]		[illegible]

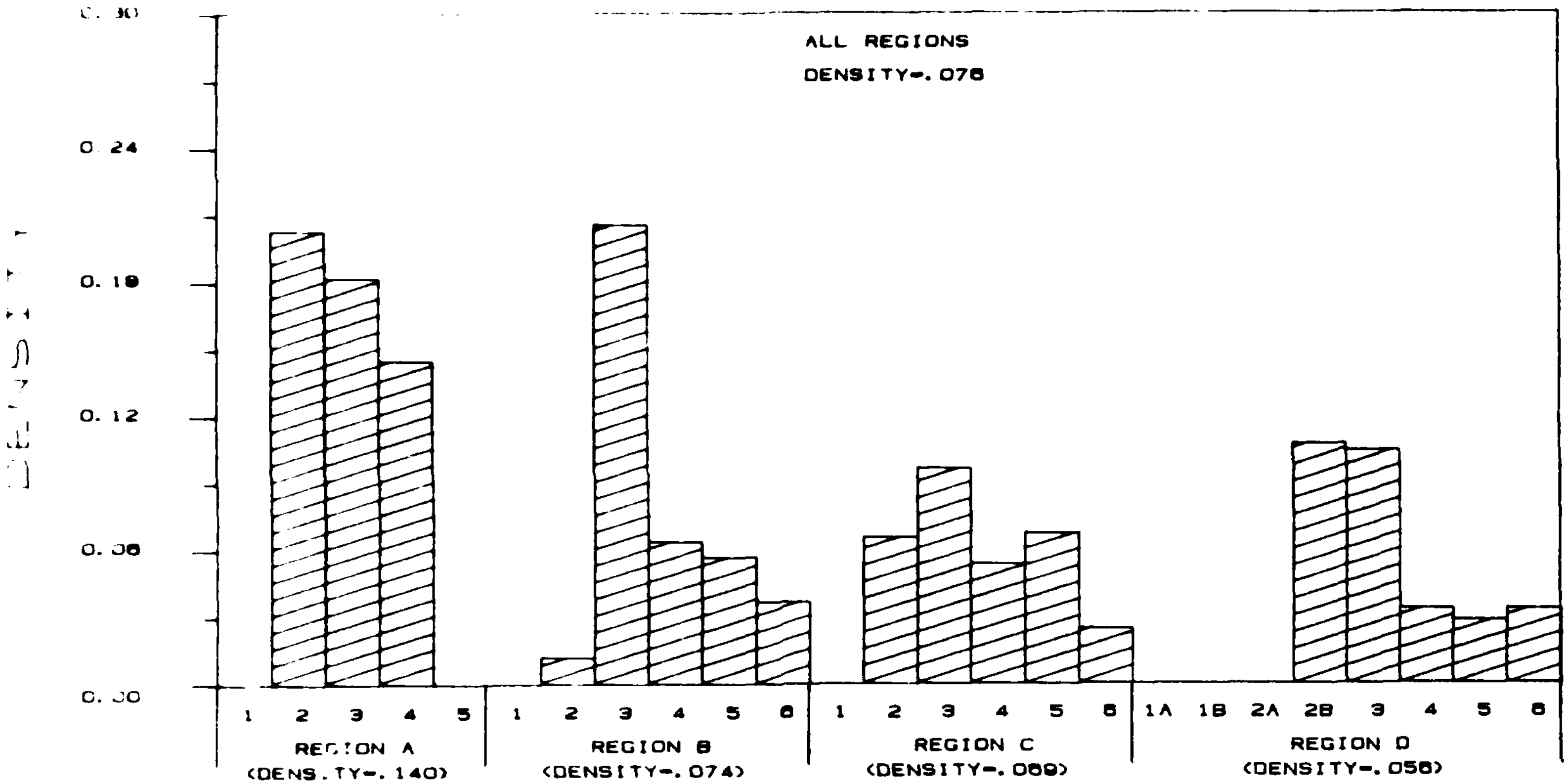


Figure B-8. Histogram of bowhead whale subregional density estimates for surveys conducted in the Beaufort Sea, September-October, 1979-86.

Table B-7. Statistics from aerial surveys of bowhead whales conducted September 1986 in the eastern Chukchi Sea. Region numbers refer to areas depicted in Figure B-7.

*The total area of all regions was approximately 66,492 km^2; areas were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Bowheads Observed	Density as Number per 100 km^2	Variance ($*10^{-4}$)	Confidence Range of Density
17	17,479	26.29	14.21	5:02	20.96	35	0	0	0	0
18	22,579	33.96	12.95	7:08	29.74	21	0	0	0	0
19	15,779	23.73	22.30	7:38	31.81	24	1	0.028	0.0003	0-0.062
20	10,655	16.02	19.19	4:12	17.48	14	0	0	0	0

Table B-8. Statistics from aerial surveys of gray whales conducted September and October 1986 in the eastern Chukchi Sea. Region numbers refer to areas depicted in Figure B-7.

*The total area of all regions was approximately 66,492 km^2; areas were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Grays Observed	Density as Number per 100 km^2	Variance ($*10^{-4}$)	Confidence Range of Density
SEPTEMBER										
17	17,479	26.29	14.21	5:02	20.96	35	6	0.242	0.0227	0-0.548
18	22,579	33.96	12.95	7:08	29.74	21	0	0.0	0.0	0
19	15,779	23.73	22.30	7:38	31.81	24	17	0.483	0.0613	0-0.995
20	10,655	16.02	19.19	4:12	17.48	14	0	0.0	0.0	0
OCTOBER										
17	17,479	26.29	15.79	6:01	27.68	44	0	0.0	0.0	0
18	22,579	33.96	3.29	1:50	8.42	6	2	0.221	0.0403	0-0.737
19	15,779	23.73	22.01	6:55	31.79	28	1	0.029	0.0060	0-0.078
20	10,655	16.02	32.63	6:59	32.11	29	0	0.0	0.0	0

Table B-9. Summary statistics from aerial surveys of gray whales conducted in the Bering and Chukchi Seas, July 1980-85.

		1980			1981			1982		
Region Name	Region Area km²	Percent of Area Surveyed	Number Grays Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Grays Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Grays Observed	Density as Number per 100 km²
1	22,438	0.0			0.0			0.11	0	0.0
2	19,036	0.0			2.23	0	0.0	0.0		
3	6,898	0.0			0.0			1.73	11	9.217
4	7,584	0.0			8.20	0	0.0	17.66	40	2.987
5	2,483	0.0			0.0			22.81	6	1.059
6	7,933	0.0			0.0			12.18	7	0.724
7	14,021	0.0			10.74	46	3.055	30.55	56	1.307
8	15,661	0.22	0	0.0	18.21	0	0.0	6.02	1	0.106
9	24,908	1.39	0	0.0	7.86	0	0.0	0.0		
10	12,608	1.23	0	0.0	13.65	14	0.813	23.18	37	1.266
11	2,631	3.69	0	0.0	36.54	5	0.520	15.73	0	0.0
12	21,214	1.52	0	0.0	7.09	9	0.598	13.85	5	0.170
13	14,200	0.46	0	0.0	10.23	0	0.0	7.30	1	0.096
14	8,468	0.0			8.29	0	0.0	6.05	0	0.0
15	19,780	0.50	0	0.0	4.73	12	1.283	0.0		
16	5,159	3.51	4	2.208	25.79	28	2.104	7.75	24	6.002
17	17,479	3.74	4	0.612	5.02	21	2.393	3.83	84	12.547

		1983			1984			1985		
Region Name	Region Area km²	Percent of Area Surveyed	Number Grays Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Grays Observed	Density as Number per 100 km²	Percent of Area Surveyed	Number Grays Observed	Density as Number per 100 km²
1	22,438	0.0			0.0			0.0		
2	19,036	1.71	0	0.0	0.0			0.0		
3	6,898	0.0			0.0			0.0		
4	7,584	9.56	0	0.0	0.0			0.0		
5	2,483	0.0			0.0			0.0		
6	7,933	11.55	65	7.094	0.0			0.0		
7	14,021	30.26	429	10.111	3.98	26	4.659	3.62	0	0.0
8	15,661	6.76	0	0.0	3.12	0	0.0	2.06	45	[illegible]
9	24,908	2.67	0	0.0	0.0			0.0		
10	12,608	19.00	346	14.443	1.32	0	0.0	6.70	71	[illegible]
11	2,631	5.00	0	0.0	6.58	0	0.0	1.64	0	0.0
12	21,214	0.62	1	0.760	1.05	0	0.0	0.0		
13	14,200	2.24	4	1.257	0.88	0	0.0	0.0		
14	8,468	0.0			0.0			0.0		
15	19,780	0.46	0	0.0	0.69	3	2.198	5.37	0	0.0
16	5,159	3.72	6	3.126	3.45	9	5.057	3.15	0	0.0
17	17,479	3.65	0	0.0	13.41	17	0.725	11.61	8	[illegible]

REFERENCES

Anderson, D.R., J.L. Laake, B.R. Crain, and K.P. Burnham. 1976. Guidelines for line transect sampling of biological populations. Utah Cooperative Wildlife Research Unit, Logan, Utah.

Burnham, K.P., D.R. Anderson, and J.L. Laake. 1980. Estimations of density from line transect sampling of biological populations. Wildl. Mono. vol. 72: 1-202.

Cox, D.R. 1958. Planning of experiments. J. Wiley, New York.

Doi, T. Further development of whale sighting theory. Chapter 16, pp. 359-368, In: The Whale Problem, W.E. Schevill (ed.), Harvard University Press, Cambridge.

Eberhardt, L.L., D.G. Chapman, and J.R. Gilbert. 1979. A review of marine mammal census methods. Wildl. Mono. vol. 63: no. 1-46.

Estes, J.A., and J.R. Gilbert. 1978. Evaluation of an aerial survey of Pacific walruses (Odobenus rosmarus divergens). J. Fish. Res. Board Can. vol. 35:1130-1140.

Hayne, D.W. 1949. An examination of the strip census method for estimating animal populations. J. Wildl. Manage. vol. 13: 145-147.

Krogman, B.D., H.W. Braham, R.M. Sonntag, and R.G. Punsley. 1979. Early spring distribution, density, and abundance of the Pacific Walrus (Odobenus rosmarus) in 1976. Outer Continental Shelf Environmental Assessment Program Research Unit 14 Final Report, no. R7120804.

Leatherwood, S., P.S. Hammond and R.A. Kastelein. (in press). Estimation of numbers of Commerson's dolphins in a portion of the northeastern Strait of Magellan, January-February, 1984. In: Cephalorhynchus, G.R. Donovan and R.L. Brownell, Jr. (eds.), Rep. int. Whal. Commn., spec. iss. 7. xxxx. (in press).

APPENDIX C

COMPILATION OF FLIGHT EFFORT, BOWHEAD WHALE SIGHTINGS AND CALL RATE IN THE ALASKAN BEAUFORT AND EASTERN CHUKCHI SEAS FROM FOUR SURVEY AIRCRAFT AND THE ACOUSTIC MONITORING STATION, SEPTEMBER-OCTOBER, 1986

INTRODUCTION

This appendix is a summary of flight effort, bowhead sightings, and call rates in the Alaskan Beaufort and eastern Chukchi Seas from 1 September to 24 October 1986, when most of the comprehensive aerial survey effort was completed. Data from four survey aircraft were compiled:

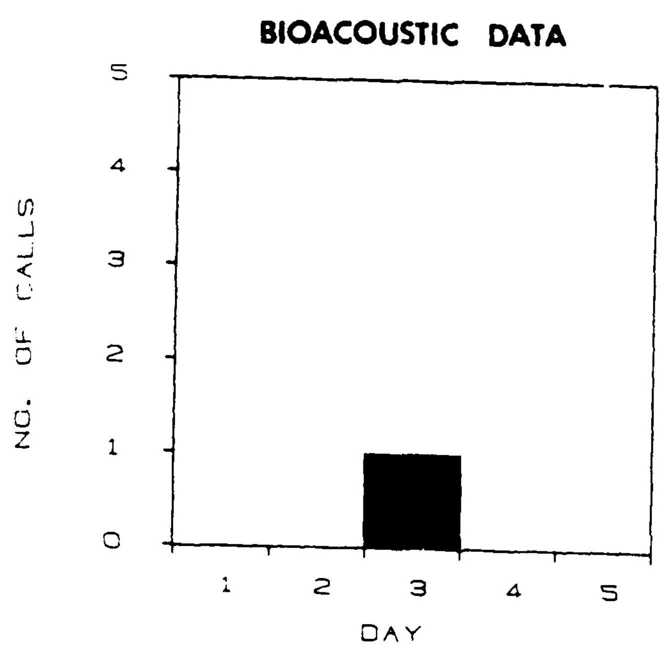
- N780 - MMS-sponsored comprehensive study to determine bowhead distribution and abundance.
- 302EH - MMS-sponsored study to assess bowhead migration status, and support of MMS sponsored bowhead tagging program;
- DHB - MMS-sponsored bowhead feeding study;
- CFIOK - Industry-sponsored study of potential drill site impact on migrating bowhead whales.

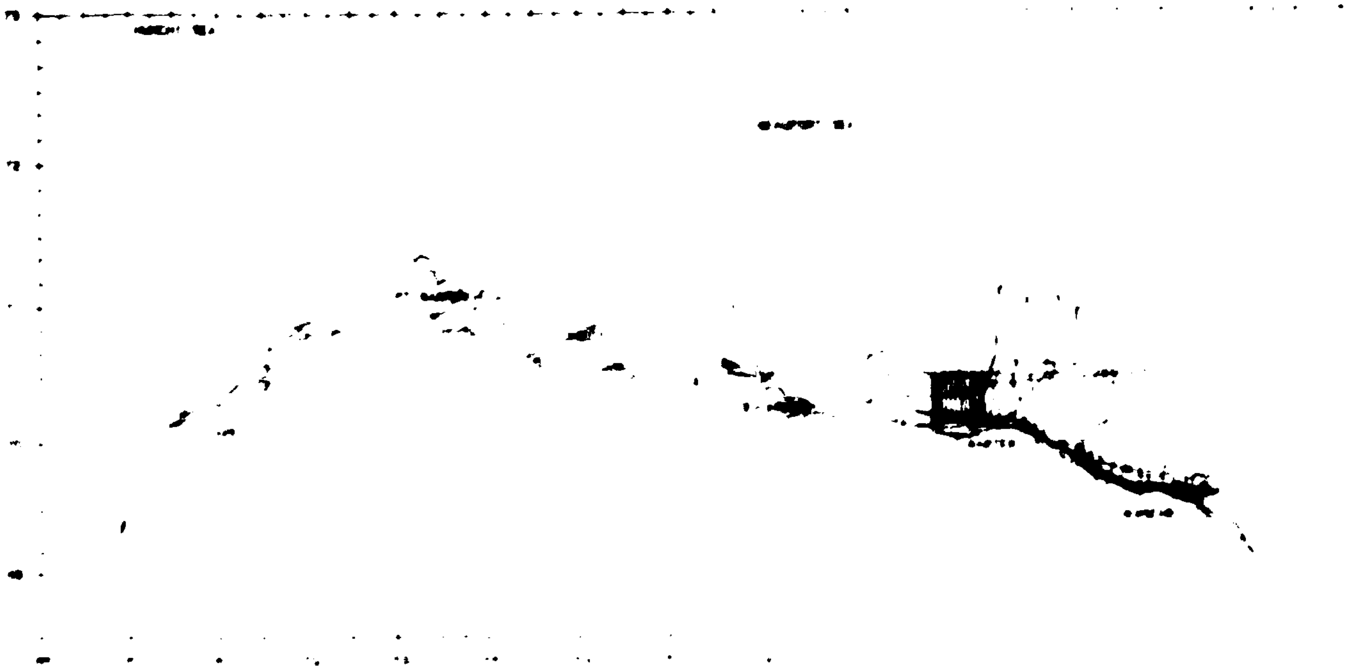
Flight effort and bowhead distribution are presented in 5-day increments and provide a comprehensive overview of the survey season. Each figure is accompanied by a descriptive summary caption. This presentation provides a depiction of bowhead migratory timing correlated with flight effort, a necessary prerequisite to interpreting whale movements. In addition, bowhead calls recorded at the acoustic station are presented in order to integrate bioacoustic and visual data, and to provide an additional indication of migratory timing. The bioacoustic data relate bowhead call rates only for the area of the eastern Alaskan Beaufort Sea near Barter Island due to the [illegible] limitations previously described for the acoustic station.

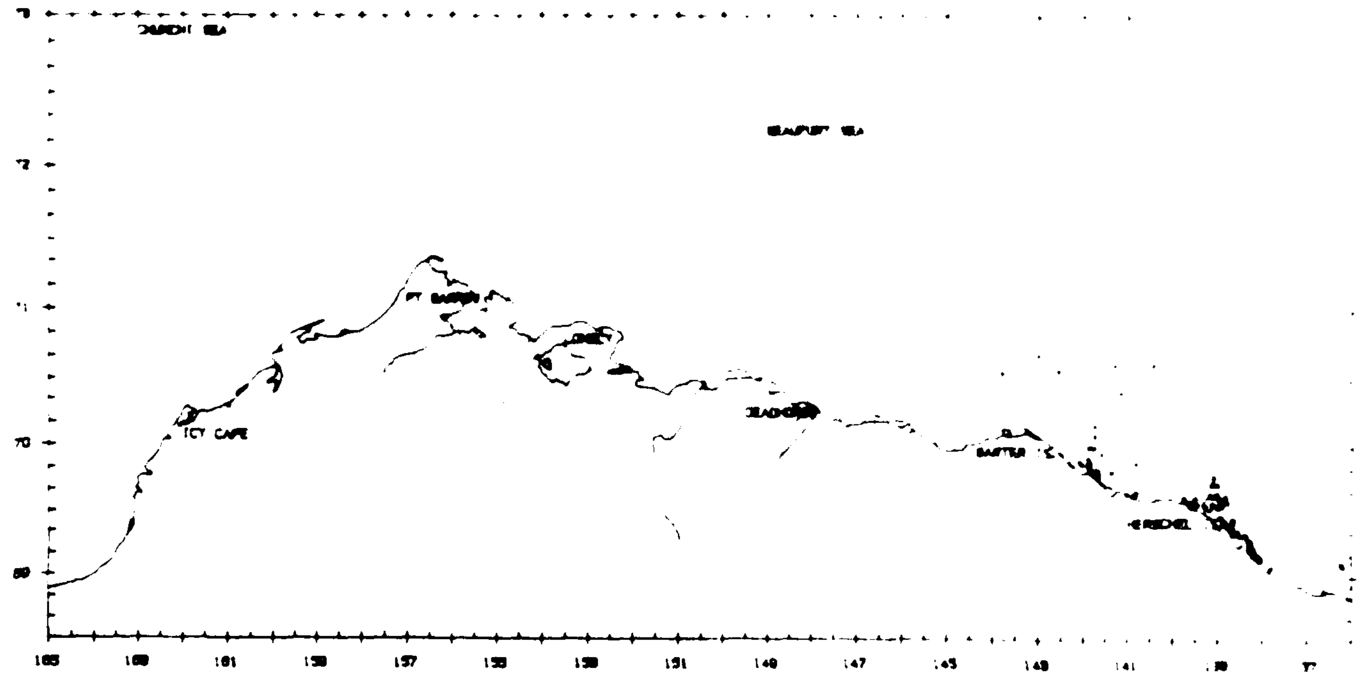
Each aircraft and crew were assigned certain priority survey areas, some of which were wide-ranging (N780, 302EH, DHB) and some of which were site-specific (CFIOK, 302EH tagging support). In some cases (N780, 302EH, CFIOK) priority survey areas shifted during the course of the season. This variation in survey effort, combined with unpredictable and often inclement weather sometimes limited survey coverage. Efforts at the acoustic station were also somewhat weather-limited. The [illegible] bioacoustic monitoring and broadscale survey coverage could not [illegible] complete [illegible] limited bowhead distribution analysis in some 5-day periods.

1-5 September 1986

Flight effort was widespread over the eastern Alaskan Beaufort Sea. Transect surveys were conducted from shore to 71°10'N between 140°W and 150°W, and search surveys were concentrated along the coast between Komakuk Beach (approx. 140°W) and Kay Point (approx. 138°20'W), Canada. Most bowhead sightings were along coastal areas, with a few sightings north and west of Barter Island, Alaska. Although survey coverage extended west to 150°W, all bowheads were seen east of 144°W. A single bowhead call was recorded at the Barter Island acoustic station on 3 September.



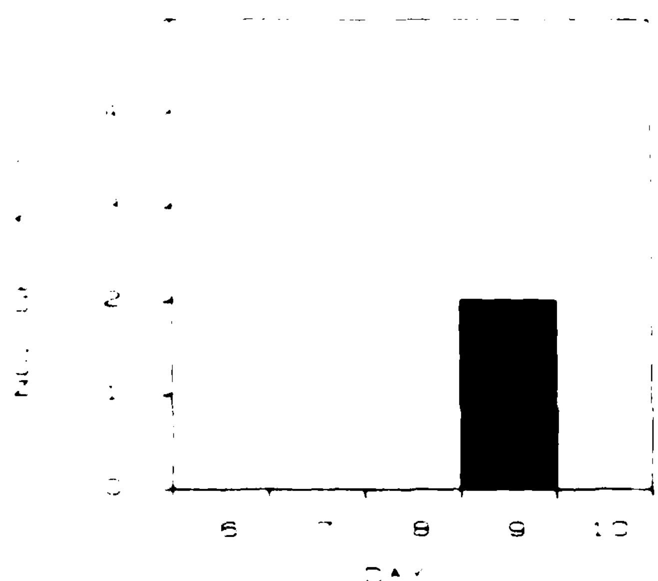


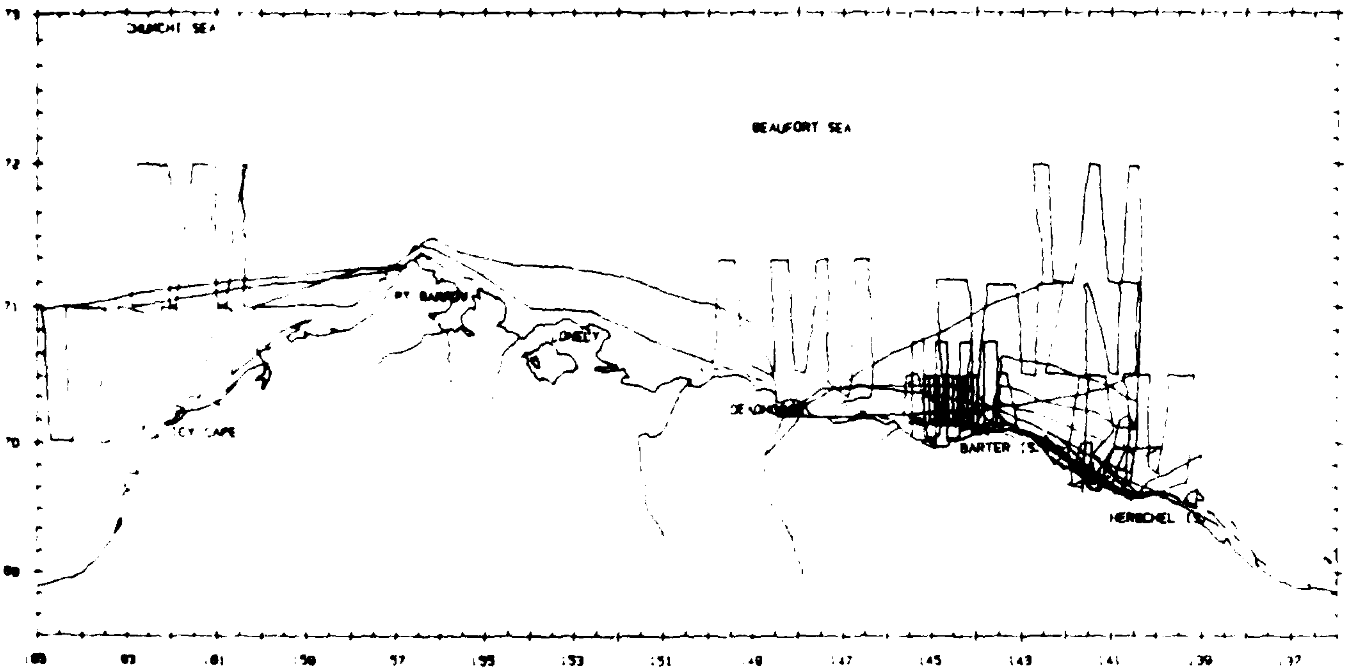

ICY CAPE
70

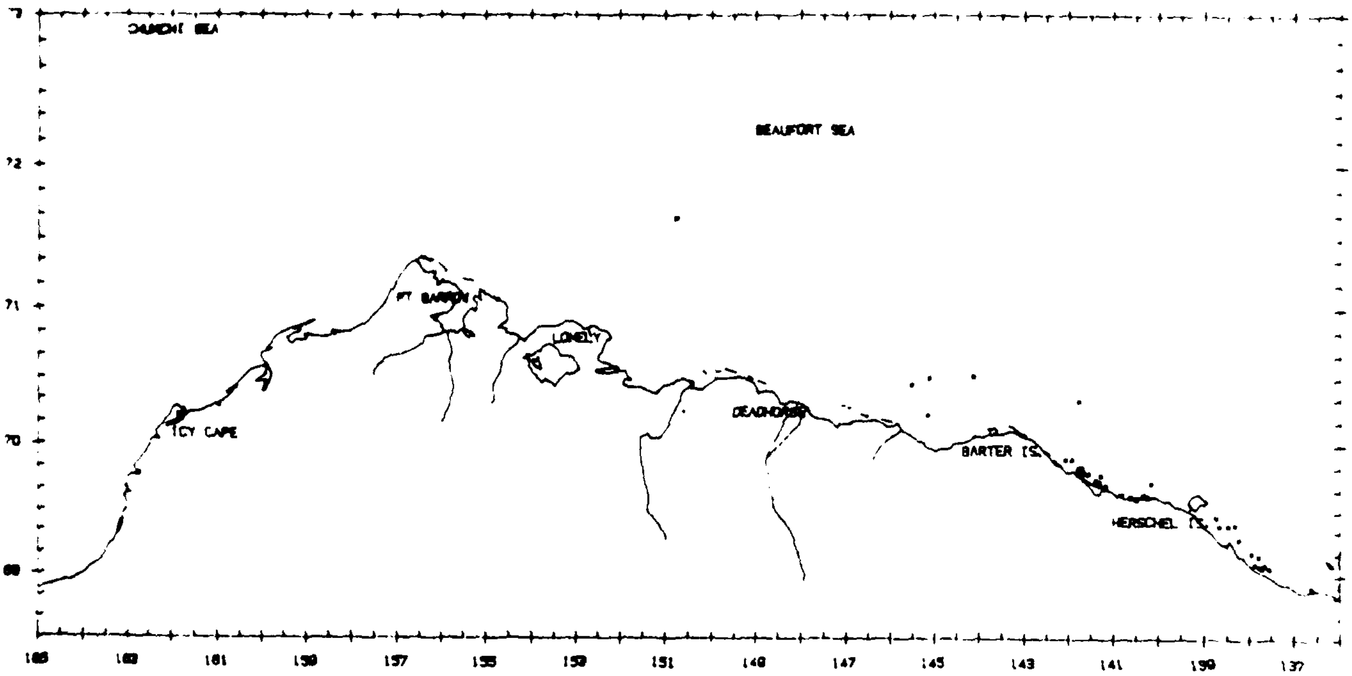
6–10 September 1986

Flight effort extended offshore to 72°N in the eastern Alaskan Beaufort Sea, with transect surveys conducted between 139°W and 150°W and search surveys flown between Barter and Herschel Islands. Two transect surveys were completed in the northeastern Chukchi Sea. Bowheads were seen predominantly nearshore east of Barter Island, with a few sightings north of Camden Bay (approx. 145°W). Two bowhead calls were recorded at the acoustic monitoring station on 9 September. The consistent sightings of bowheads in the Alaskan Beaufort Sea prompted the NMFS to officially recognize the onset of the migration on 10 September. No bowheads were seen in the Chukchi Sea.

BIOACOUSTIC DATA

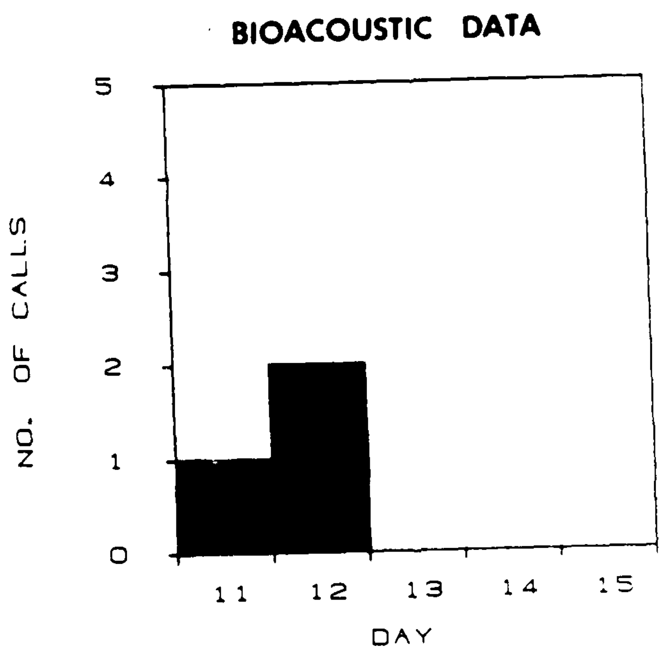


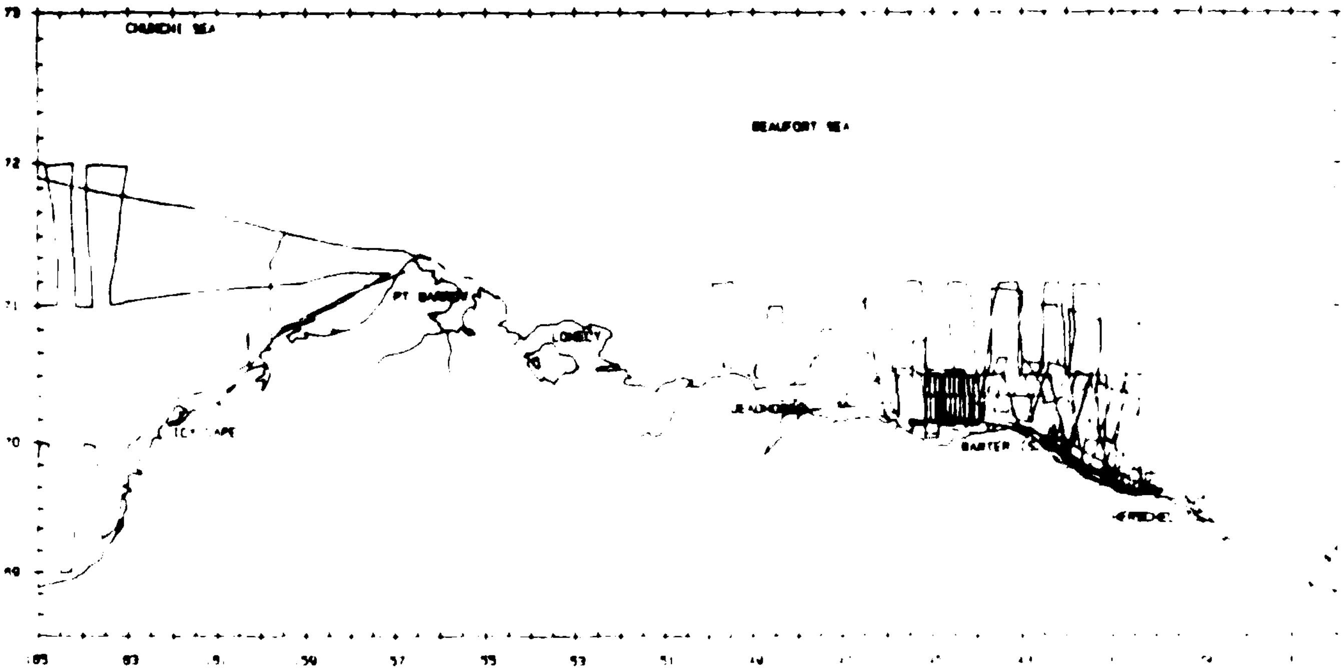

BEAUFORT SEA
PT BARROW
ICY CAPE
BARTER IS.
HERSCHEL IS.

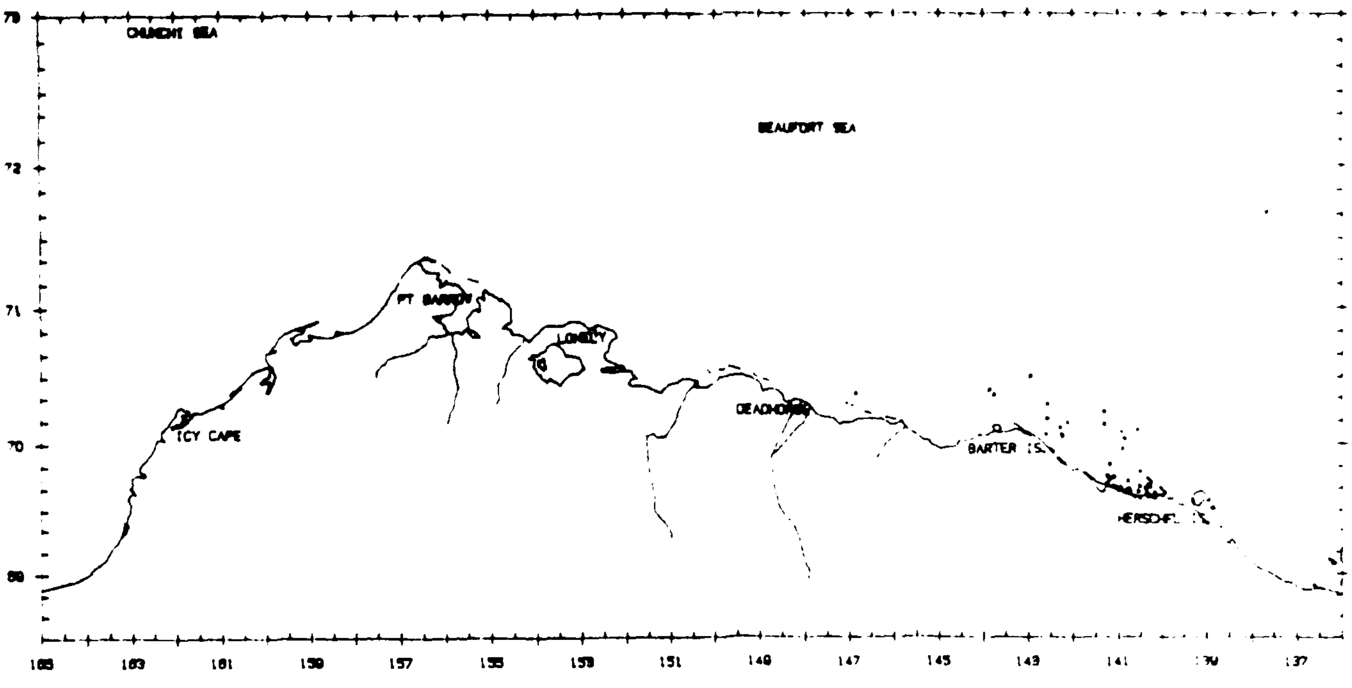

BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.

11-15 September 1986

Flight effort extended from shore to 71°10'N in the eastern Alaskan Beaufort Sea, with numerous behavioral surveys flown between Barter Island and Komakuk Beach. Survey effort in the Chukchi Sea was offshore and/or in the southernmost regions of the study area. Bowhead distribution was concentrated east of Barter Island, with a single sighting northeast of Deadhorse, indicating that the bulk of the population remained east of Barter Island through mid-September. Three bowhead calls were recorded; one on 11 September and two on 12 September. No bowheads were seen in the Chukchi Sea.

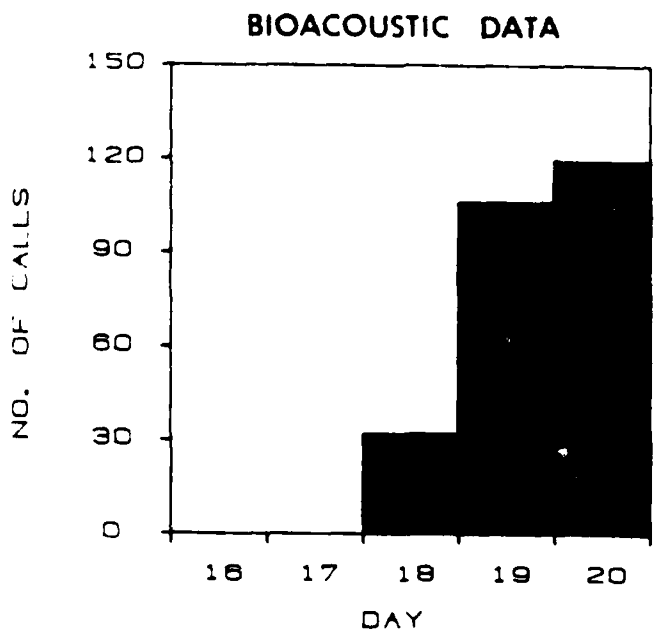


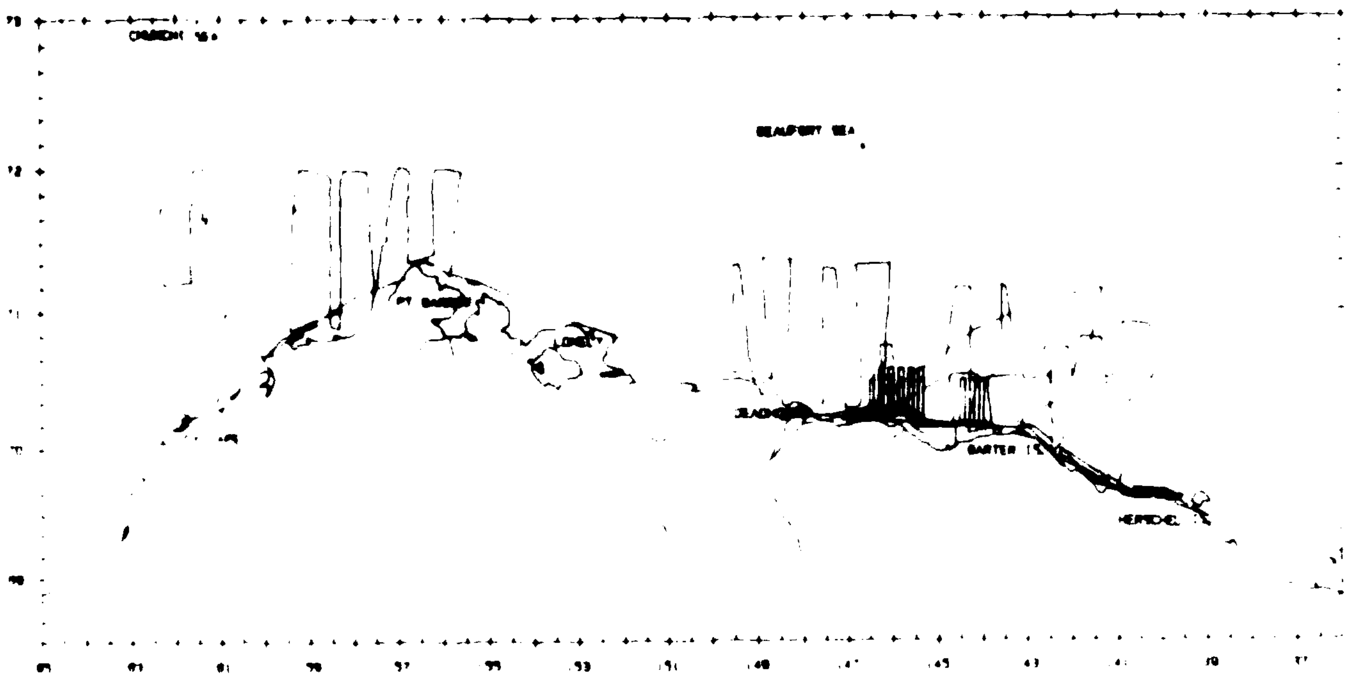

BEAUFORT SEA
PT BARROW
ICY CAPE
BARTER IS.

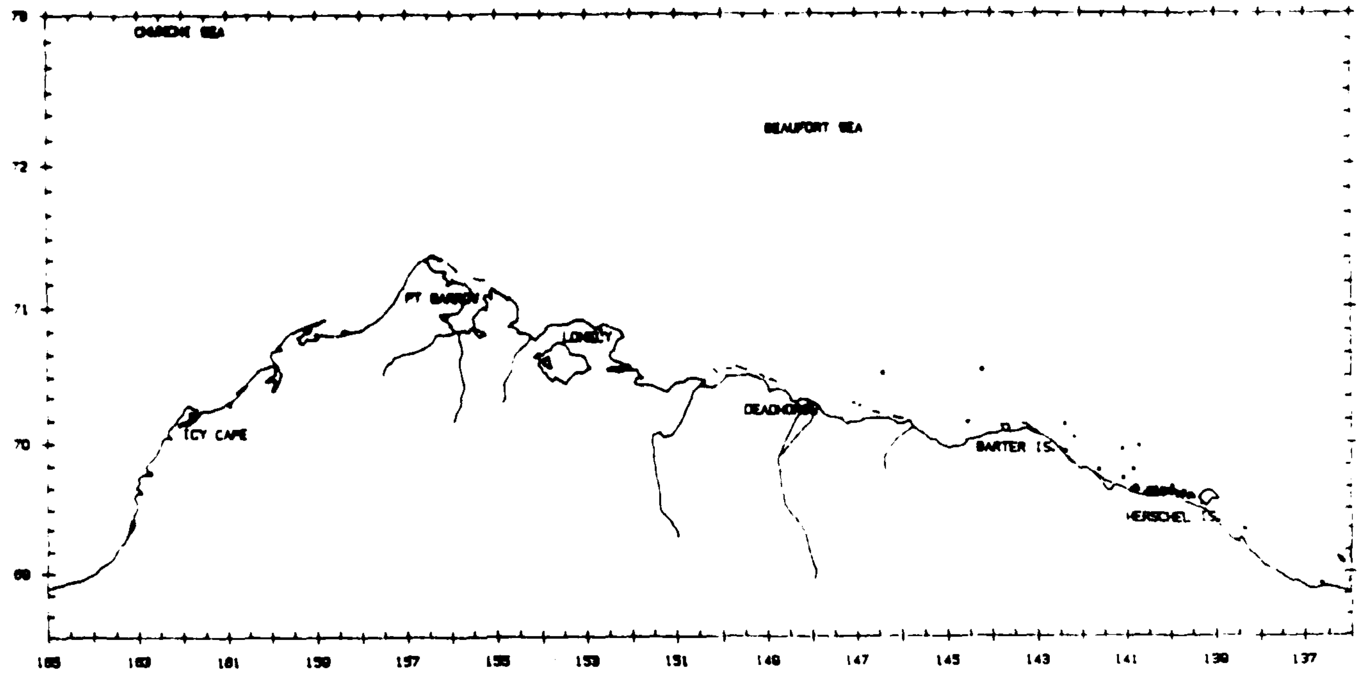

CHUKCHI SEA
BEAUFORT SEA
PT BARROW
ICY CAPE
DEADHORSE
BARTER IS.
HERSCHEL IS.

16-20 September 1986

Flight effort was concentrated in the eastern Alaskan Beaufort Sea, especially nearshore between Barter Island and Komakuk Beach. Again, numerous behavioral surveys were completed in the nearshore eastern Alaskan Beaufort and consequently, the majority of bowhead sightings were in that area, with scattered sightings as far west as 146°30'W. Bowhead calls were recorded at the Barter Island acoustic station; 32 on 18 September, 106 on 19 September and 119 on 20 September. No bowheads were seen in the Chukchi Sea although transect surveys were completed in nearshore areas within the assumed migratory path.

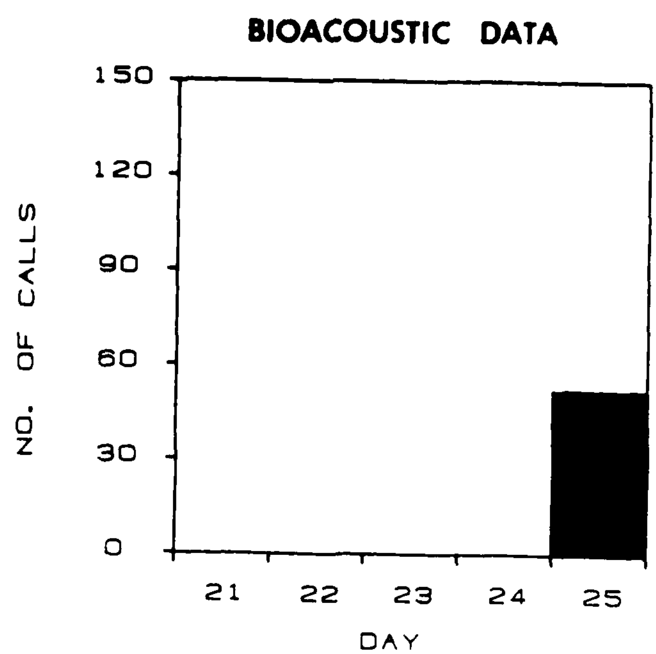


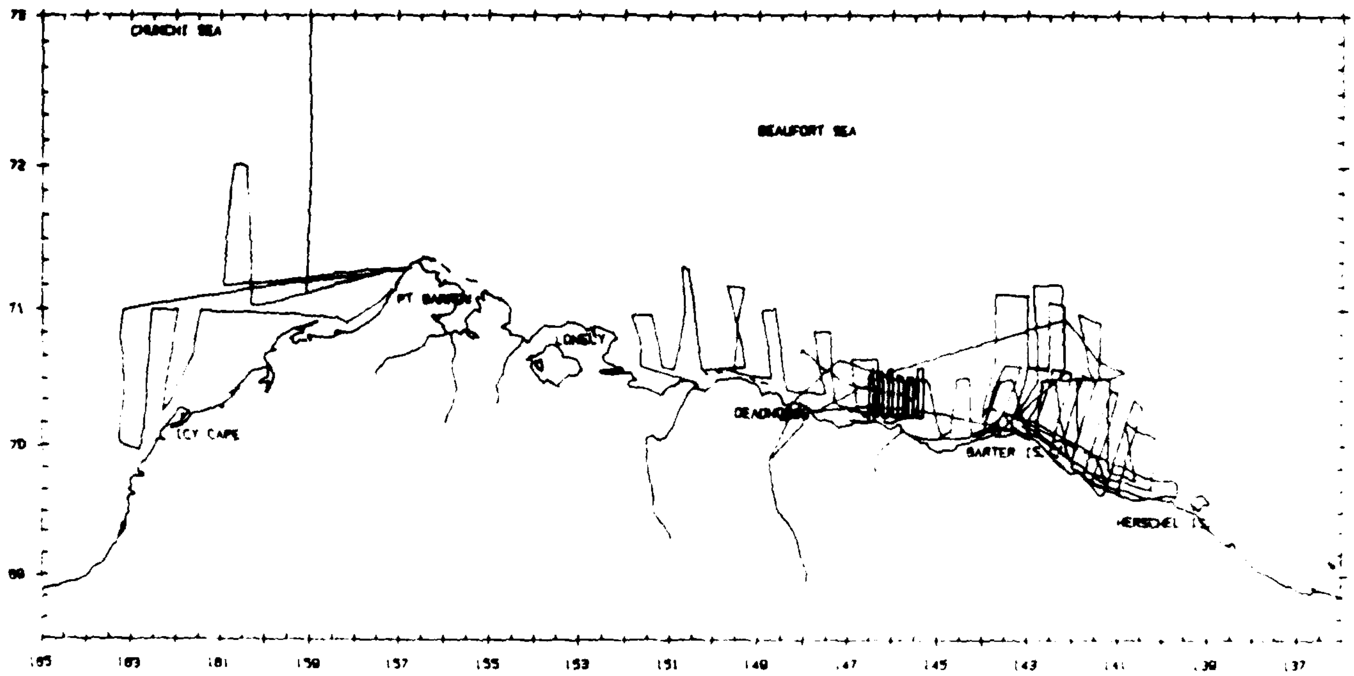

BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
BARTER IS.
HERSCHEL

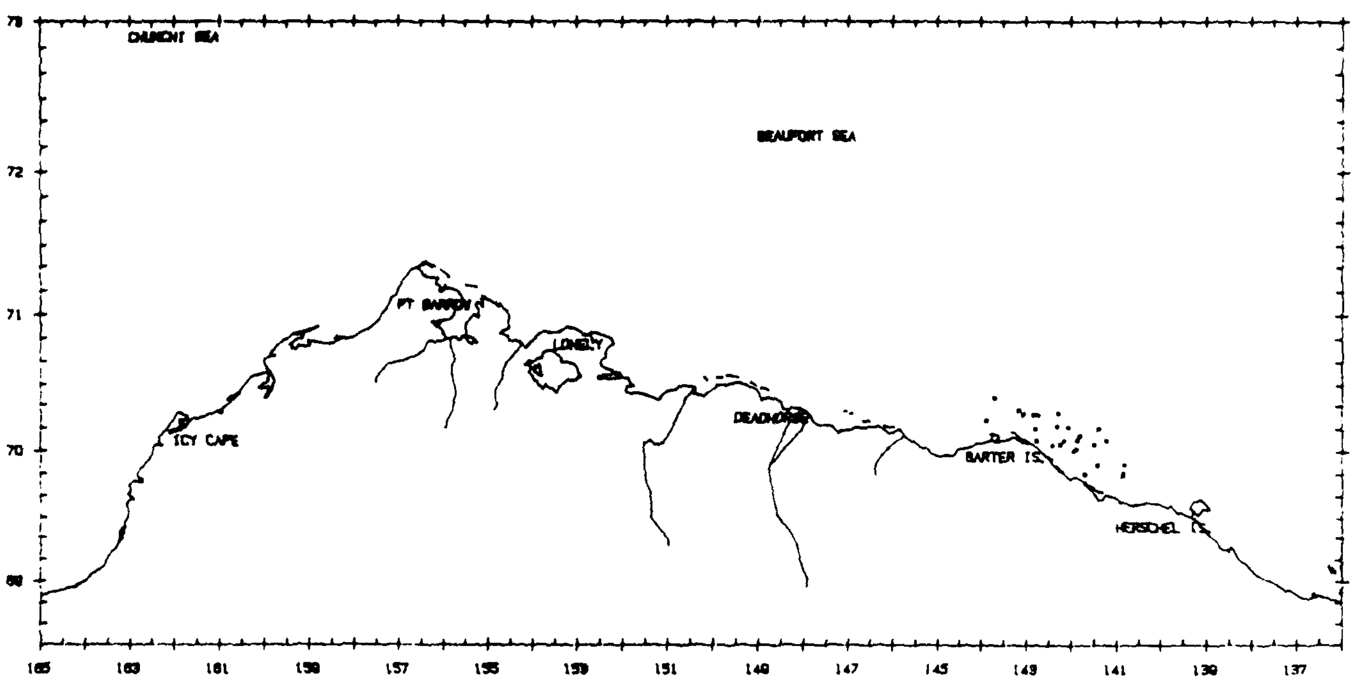

CHUKCHI SEA
BEAUFORT SEA
72
71
70
69
PT BARROW
LONELY
ICY CAPE
DEADHORSE
BARTER IS.
HERSCHEL IS.
163
161
159
157
155
153
151
149
147
145
143
141
139
137

21-25 September 1986

Flight effort in the Alaskan Beaufort Sea was concentrated north and east of Barter Island, northwest of Camden Bay and west to 152°W. Bowhead distribution was generally clumped between Barter Island and Demarcation Bay. Fifty-two bowhead calls were recorded on 25 September at the acoustic station. Inclement weather prevented extensive surveying in the northeastern Chukchi Sea.

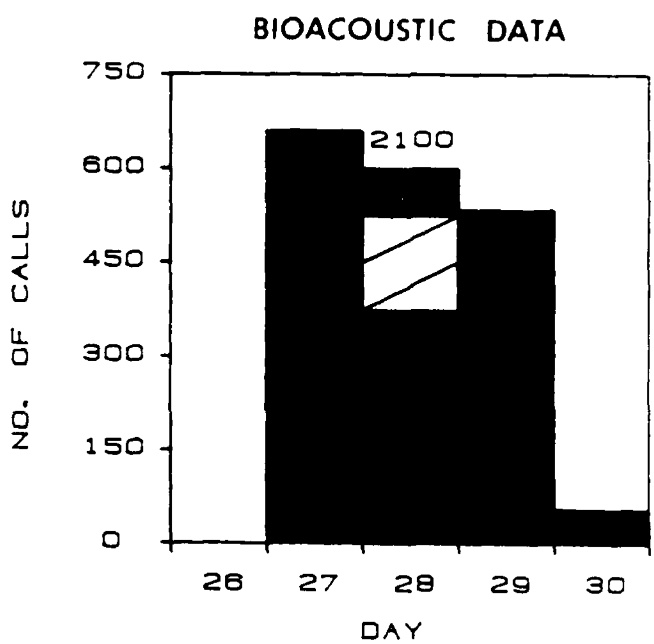


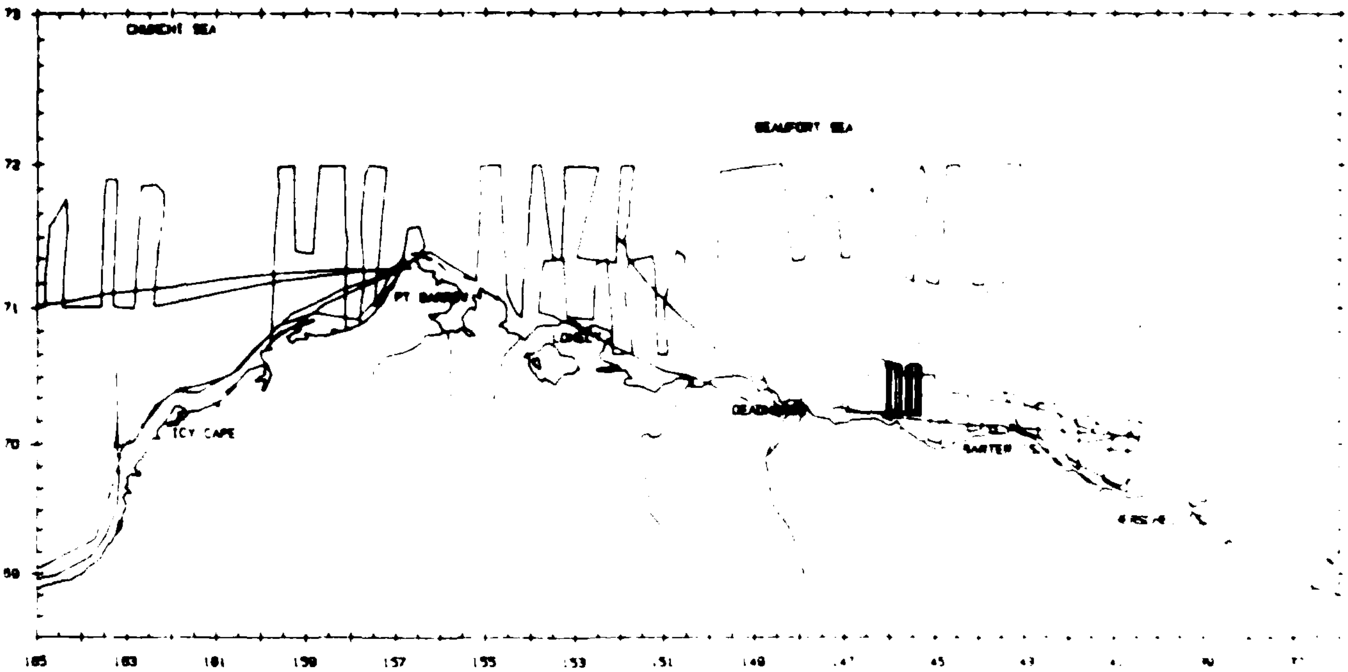

CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.

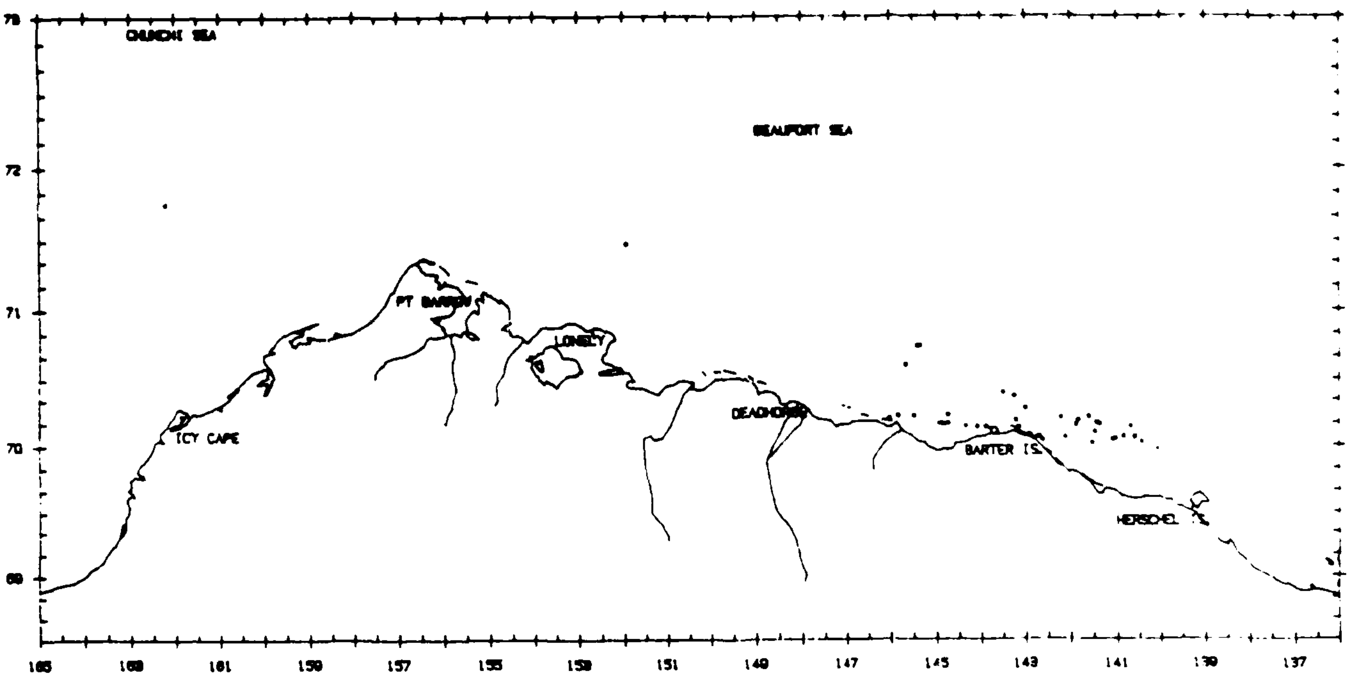

CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.

26-30 September 1986

Flight effort encompassed broad areas of both the Alaskan Beaufort and northeastern Chukchi Seas. Bowhead distribution extended from approximately 140°W to 146°30'W, with one whale seen northwest of Harrison Bay and one whale seen in the Chukchi Sea. This time period corresponded with peaks in call rate (to 2100 calls on 28 September) and WPUE peaks indicating appreciable movements of bowheads into the Alaskan Beaufort Sea.

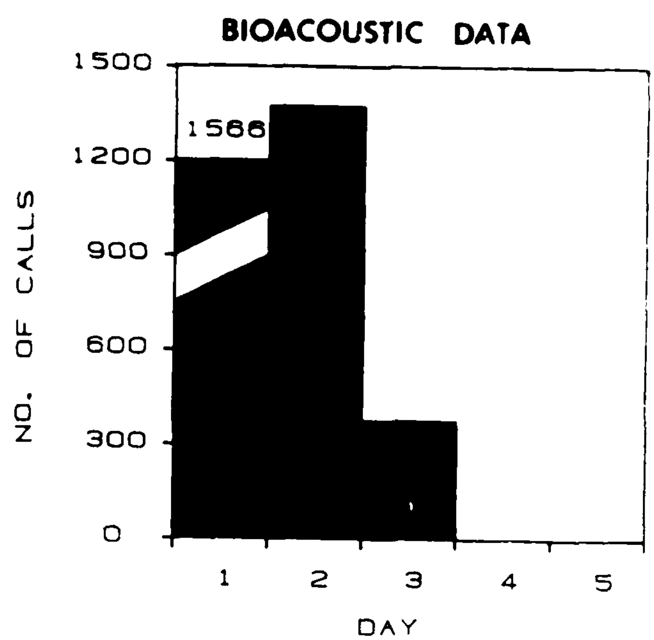


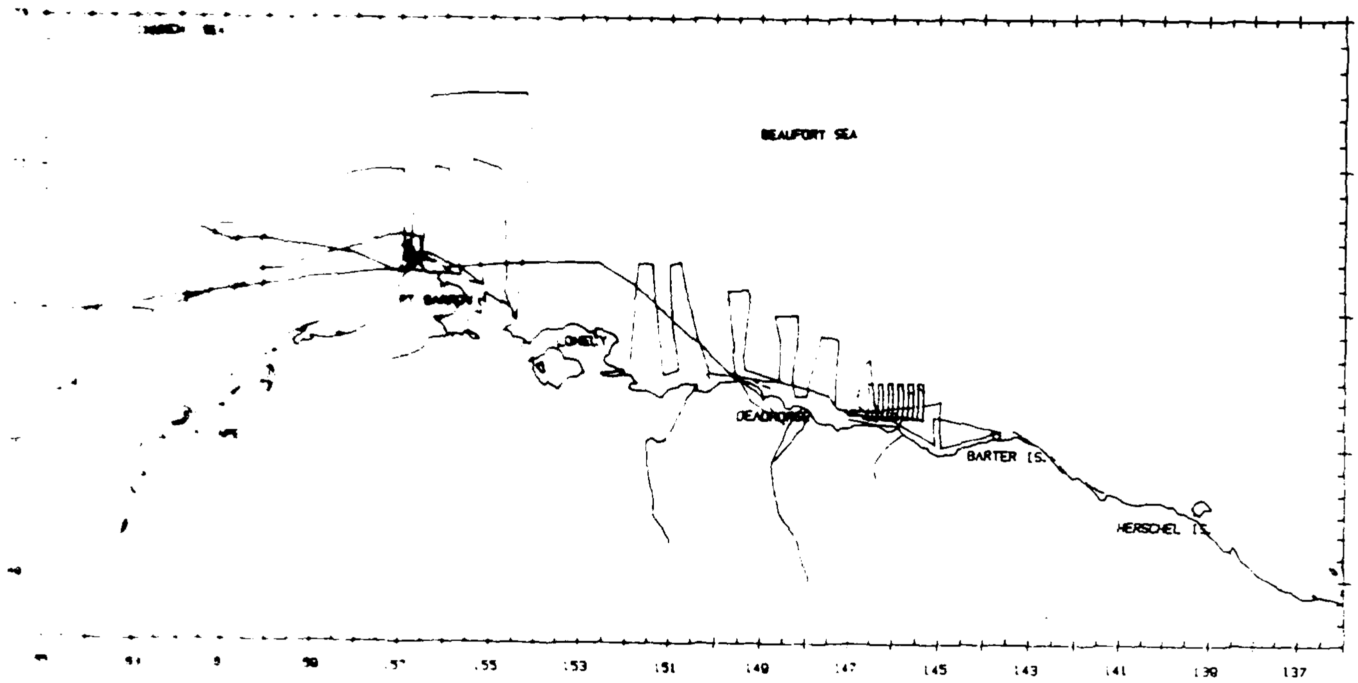

CHUKCHI SEA
BEAUFORT SEA
PT BARROW
ICY CAPE
DEADHORSE
BARTER IS
73
72
71
70
69
165
163
161
159
157
155
153
151
149
145
143

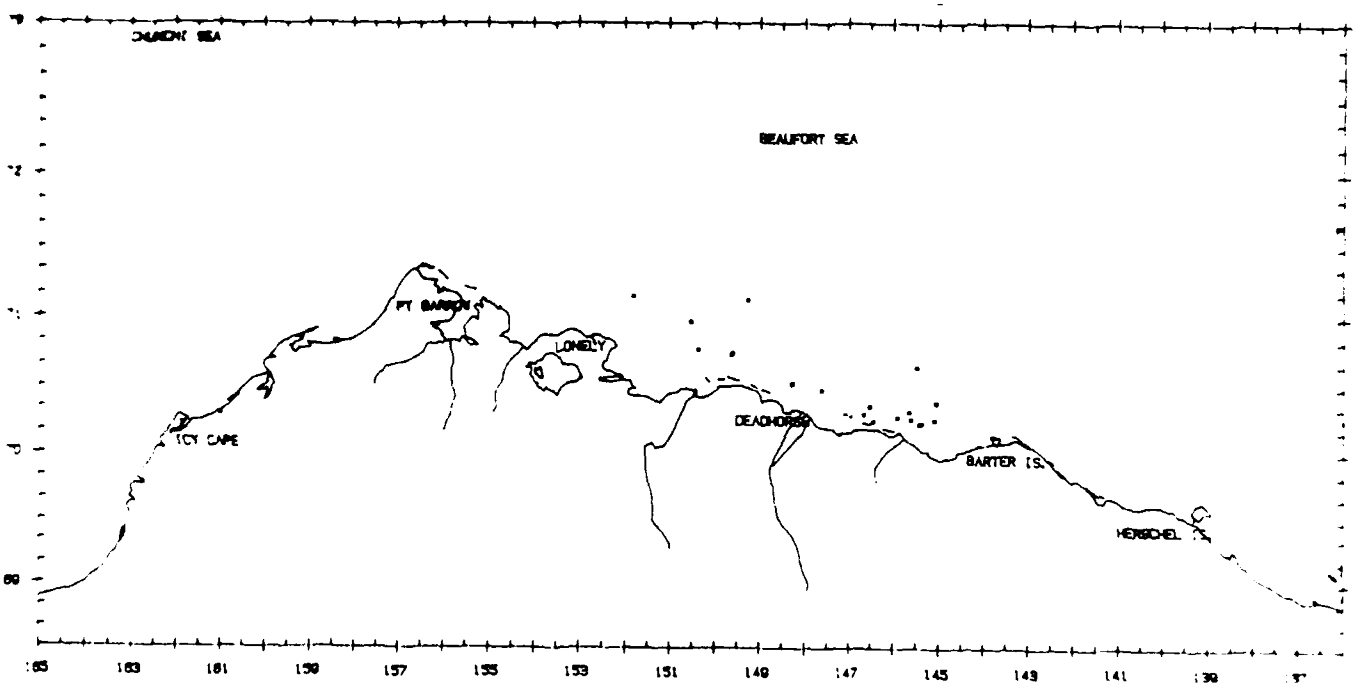

CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
ICY CAPE
DEADHORSE
BARTER IS.
HERSCHEL IS.
73
72
71
70
69
165
163
161
159
157
155
153
151
149
147
145
143
141
139
137

1-5 October 1986

Flight effort was concentrated between Barter Island and Harrison Bay and northeast of Pt. Barrow in the Alaskan Beaufort Sea, and in the nearshore areas of the northeastern Chukchi Sea. Bowhead distribution extended from Camden Bay to north of Harrison Bay. Based upon patterns of distribution in late September it is highly likely that bowheads remained in the Alaskan Beaufort Sea east of Barter Island, but no flights were flown in that area. Bowhead call rate remained high near Barter Island, however, with peaks of 1566 calls on 1 October and [illegible] calls on 2 October. There were no bowheads seen in the northeastern Chukchi Sea.



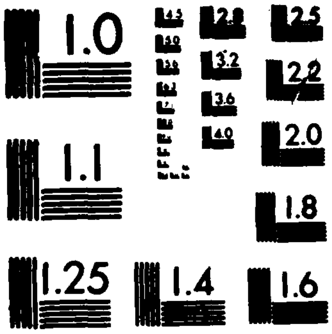

BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
BARTER IS.
HERSCHEL IS.
145
143
141
139
137


BEAUFORT SEA
PT BARROW
LONELY
ICY CAPE
DEADHORSE
BARTER IS.
HERSCHEL IS.
163
161
159
157
155
153
151
149
147
145
143
141
139

AD-A183 934 DISTRIBUTION ABUNDANCE BEHAVIOR AND BIOACOUSTICS OF ENDANGERED WHALES IN T..(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA D K LJUNGBLAD ET AL. JUL 87 NOSC/TR-1177 5/5

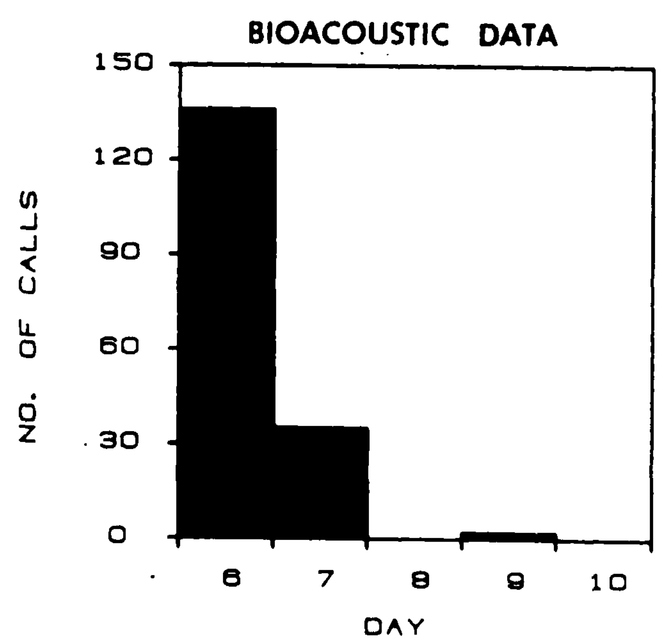
UNCLASSIFIED F/G 8/1 NL

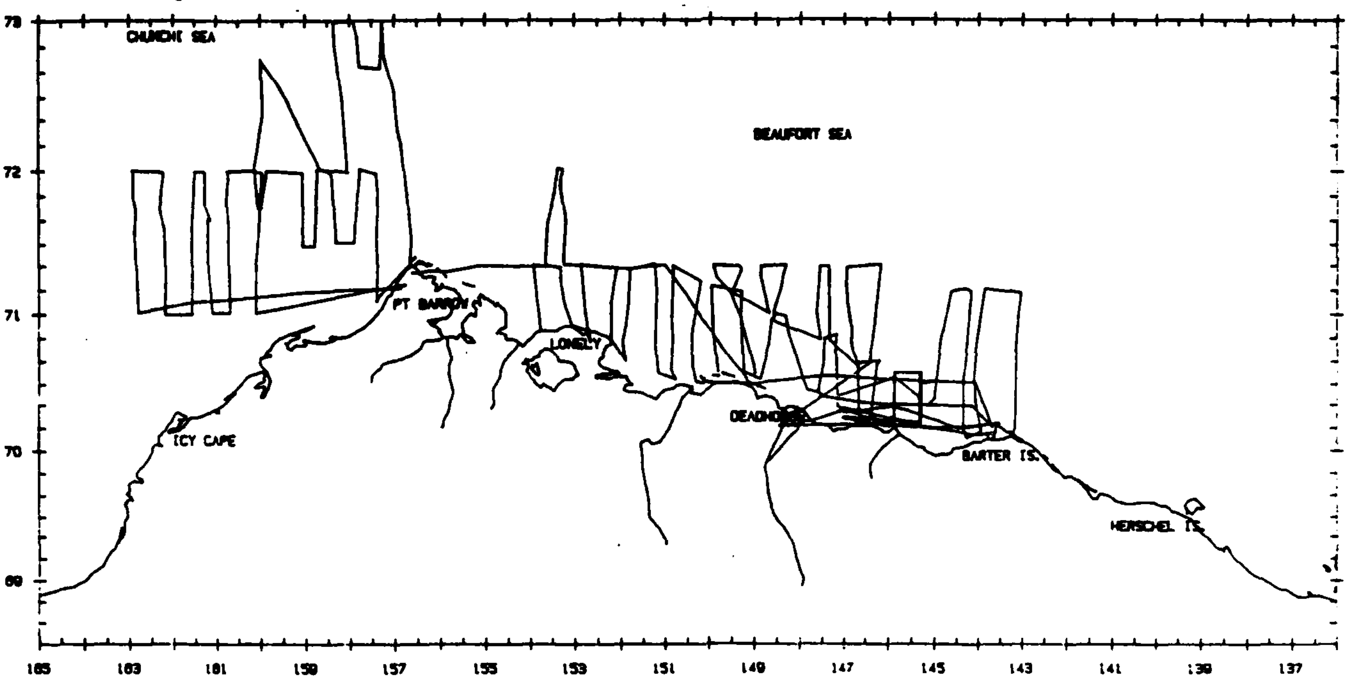
END
9-87
DTIC

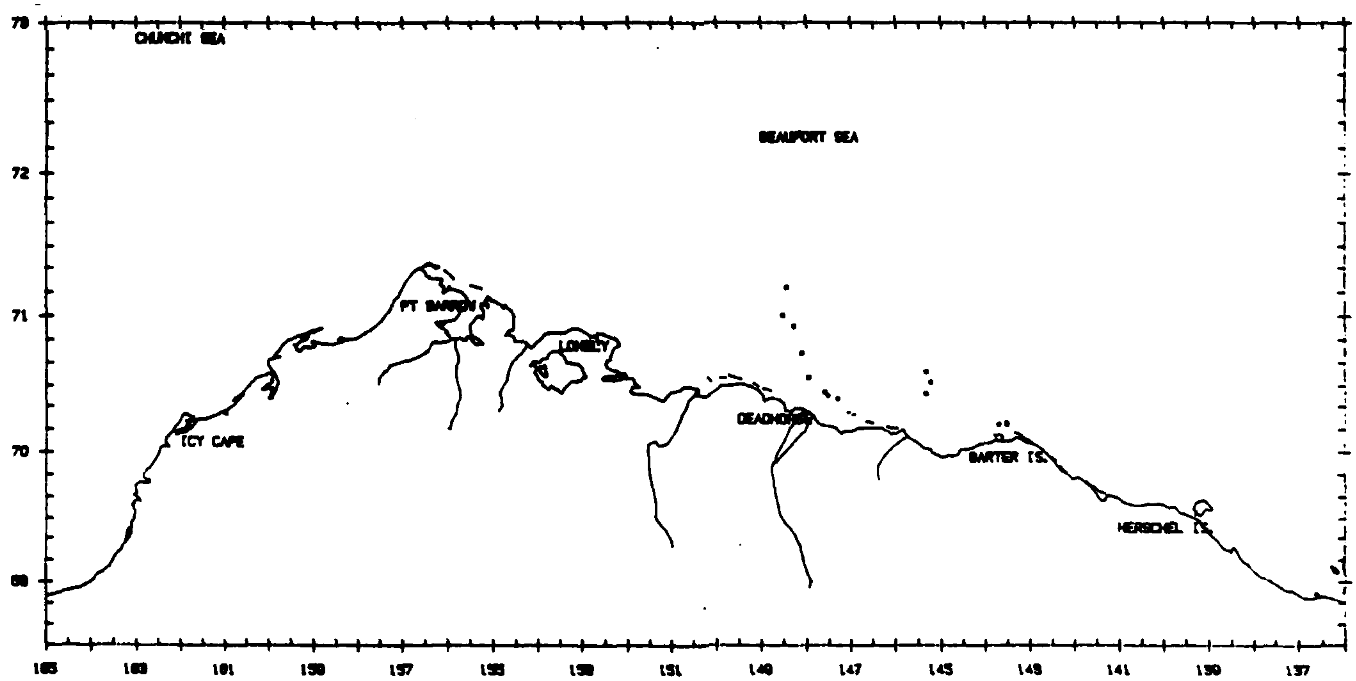

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

6-10 October 1986

Flight effort extended across the Alaskan Beaufort Sea west of Barter Island and through the northern portions of the Chukchi Sea study area. Bowheads were seen between Barter Island and eastern Harrison Bay; no bowheads were seen in the Chukchi Sea. Again, no surveys were completed east of Barter Island and the presence or absence of bowheads in that area was unconfirmed visually. One hundred seventy-three bowhead calls were recorded at the acoustic station; 136 of them on 6 October, indicating that an aggregation of whales remained in the vicinity of Barter Island through early October.

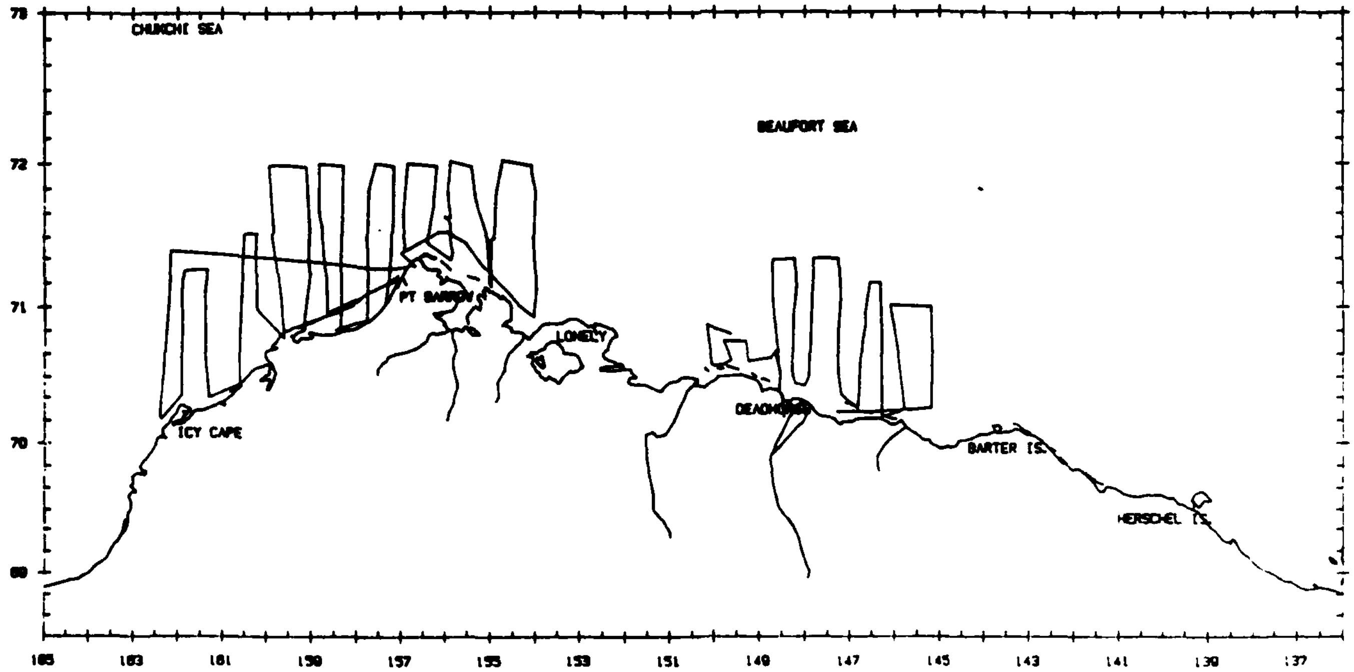



CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.
73
72
71
70
69
165
163
161
159
157
155
153
151
149
147
145
143
141
139
137

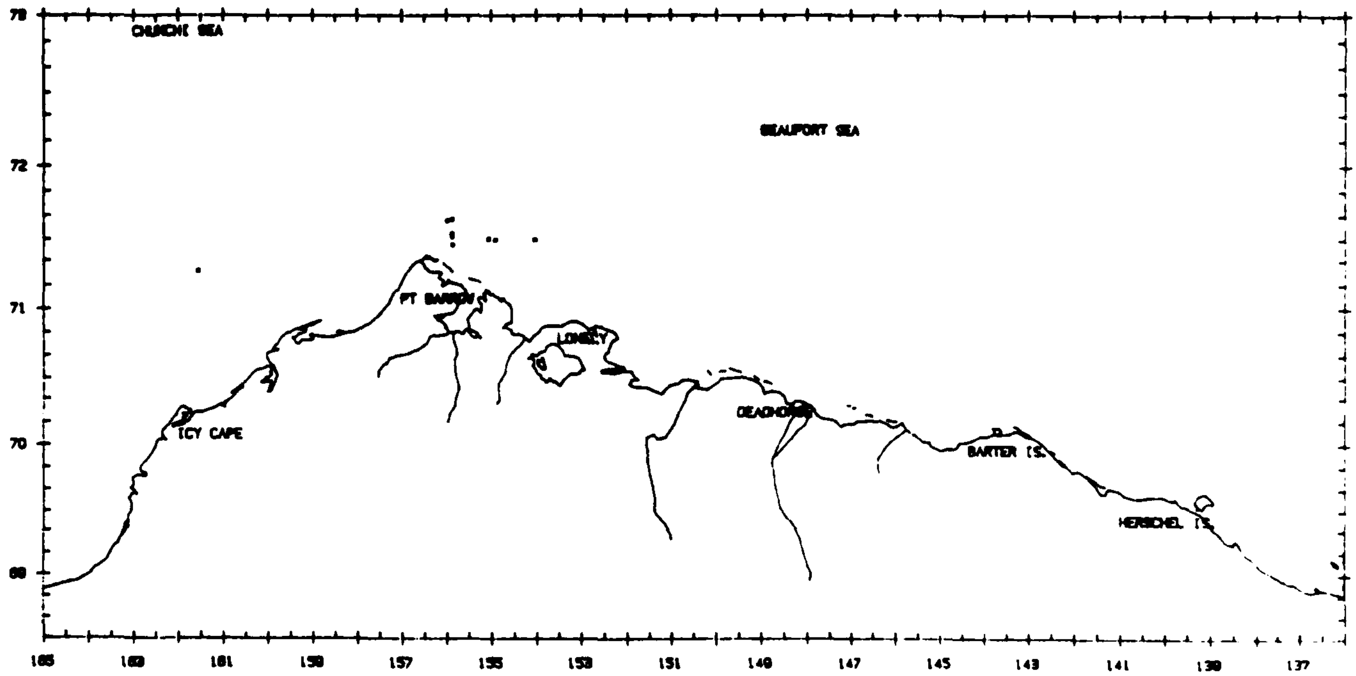

CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.
73
72
71
70
69
165
163
161
159
157
155
153
151
149
147
145
143
141
139
137

11-15 October

Flight effort was centered north of Deadhorse in the Alaskan Beaufort Sea and over the northern coastal areas of the Chukchi Sea. Bowheads were seen northeast of Pt. Barrow in the western Alaskan Beaufort Sea, with one also seen in the Chukchi Sea. The last day of operation for the acoustic station was 11 October, and no bowhead calls were recorded.



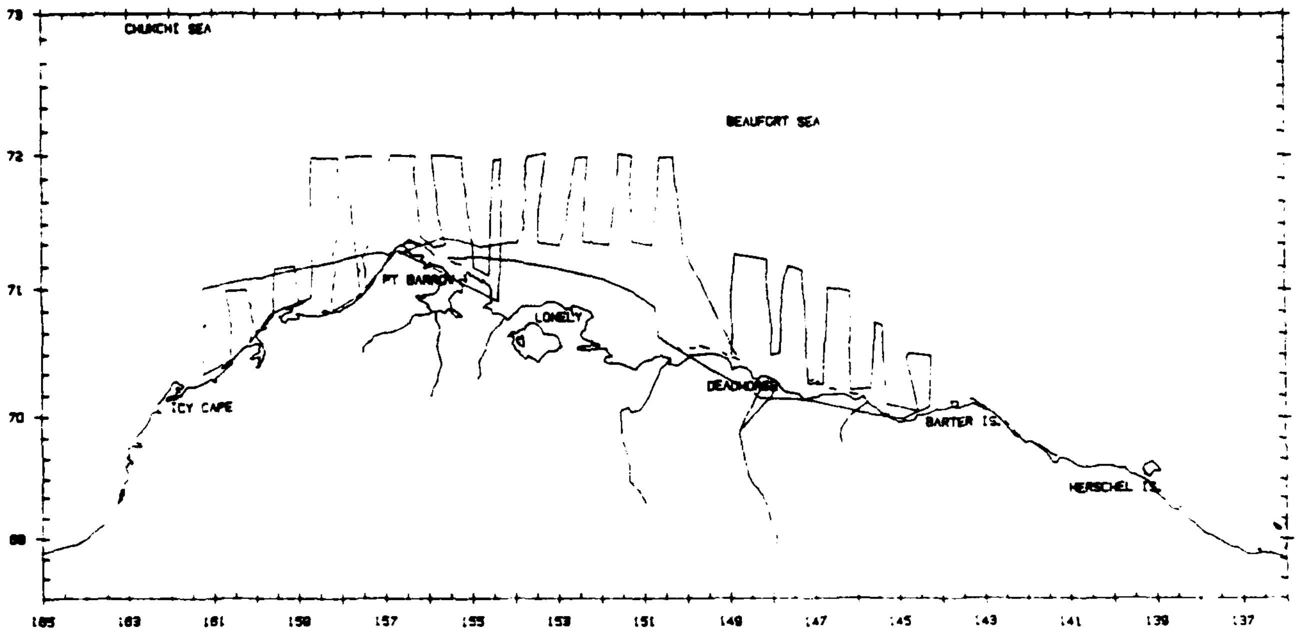
CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.

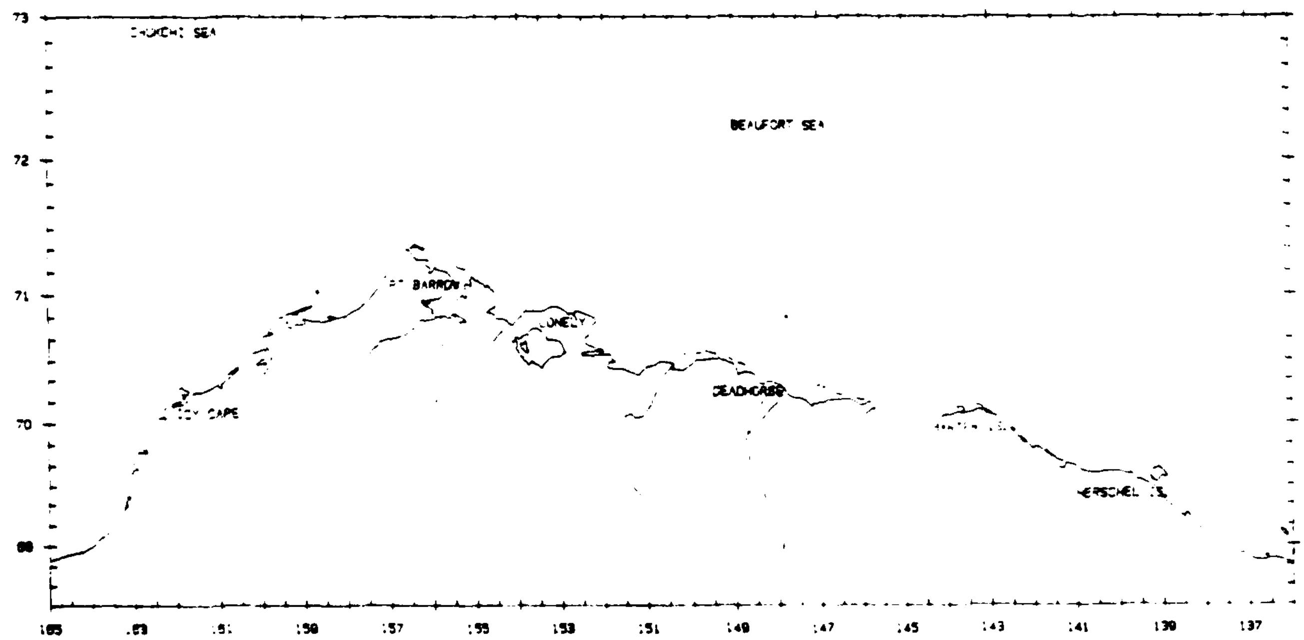


CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.

16-20 October

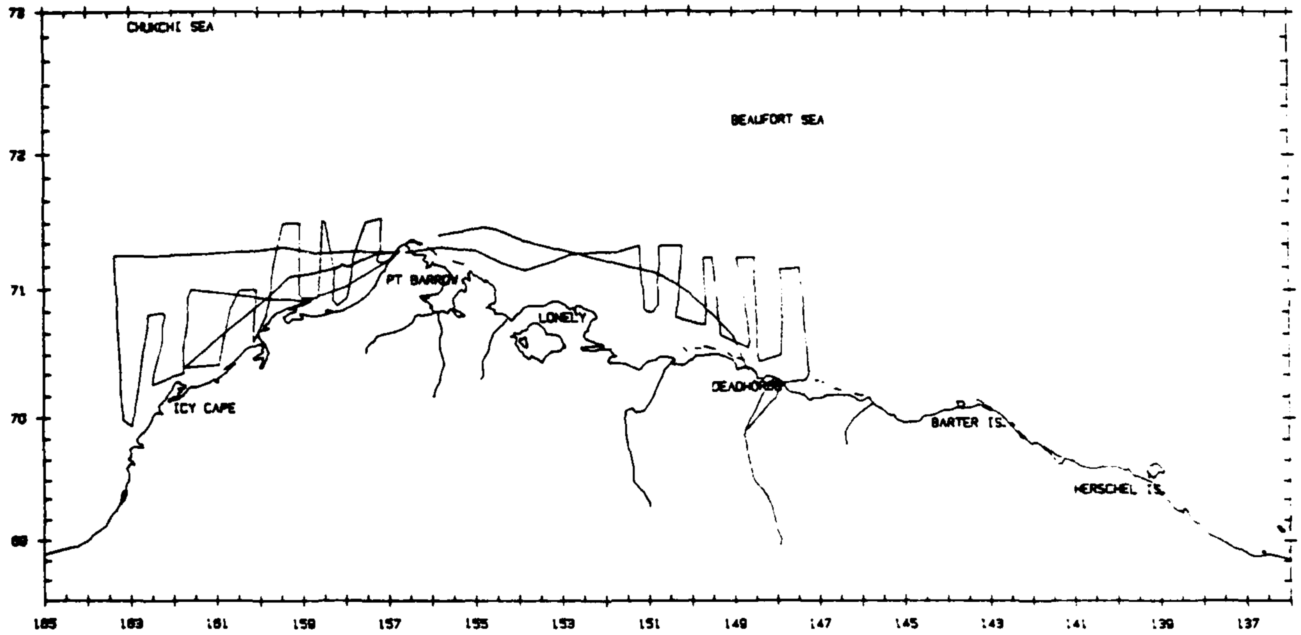
Flight effort was centered north of Deadhorse in the Alaskan Beaufort Sea and over the northern coastal areas of the Chukchi Sea. Two bowheads were seen southwest of Pt. Barrow in the Chukchi Sea, with one also seen in the Beaufort Sea north of Deadhorse.


CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
ICY CAPE
BARTER IS.
HERSCHEL IS.
73
72
71
70
69
165
163
161
159
157
155
153
151
149
147
145
143
141
139
137


BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
HERSCHEL IS.
73
72
71
70
69
165
159
157
155
153
151
149
147
145
143
141
139
137

21-24 October

Flight effort covered areas in the central Alaskan Beaufort and coastal northeastern Chukchi Seas. No bowheads were seen. No survey flights were completed after 24 October.



CHUKCHI SEA
BEAUFORT SEA
PT BARROW
LONELY
ICY CAPE
DEADHORSE
BARTER IS.
HERSCHEL IS.

END
9-87
DTIC